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The Use of RFID Technology for Improved Production Control

A Design Science Approach

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Global Manufacturing Management
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MASTER THESIS

FOR

STUD. TECHN. SONDRE SIVESIND MELBYE

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- A Design Science Approach

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Abstract

Purpose

In an increasingly globalized world, the competition increases from international companies. As a result, more production is moved outside of domestic borders to reduce costs. At the same time, there is a need for Norwegian companies to reduce labor costs. By Norwegian workers possessing a high technological level, and technology being a measure towards reduction of labor costs, the justification for doing research on digitalization in the Norwegian industry is given.

Auto-ID technology, for example Radio Frequency Identification, has the ability to capture data in a real time manner. This can support production planning and control, enabling fast dealing of deviations in production. It can also facilitate the automation of manual tasks to reduce labor costs. However, there is a lack of research on RFID being applied in facility process management. This gap is addressed in this research. The objective of this study is to investigate benefits and drawbacks to RFID technology in the area of facility process management. This research will do so by illustrating how a Norwegian company can benefit from RFID technology in production control. Hence, the selected research aim to *investigate how RFID can support production control*.

Design

The research applies a design science research methodology. An approach focusing on *"improving the present"*, based on a theoretical- and a practical component. The theoretical component is solved by performing a structured literature study on RFID technology. The practical component is solved through designing an RFID system for implementation at the production facility of Pipelife Norge AS in Surnadal.

Findings

The study as been able to propose an RFID system for Pipelife Norge AS, where their current challenges was addressed. In addition, the main benefits and challenges to RFID technology was identified. The benefits were identified to be autonomous registration and identification in real-time, simultaneously registering of multiple units, no need for line-of-sight. The challenges can be separated in two categories: strategic and technical challenges. Strategic challenges include the three *"high problems"*. Technical challenges include interference and the use of different languages across different RFID-systems.

The identified benefits RFID has the potential to support decision-making by providing the decision maker with the current status of the system, hence providing a better foundation for decision making. RFID technology can also automate manual tasks, especially registering tasks. The use of RFID technology may illustrate an emerging shift in focus for production planners from planning towards production control.

Research Limitations/Implications

For researchers, this research serves as a collection of the most relevant research within the topic. The main benefits and challenges are identified and summarized. This can serve are a basis of doing deductive research on the mechanisms producing these outcomes.

However, there is a limitation in that human factors is excluded from this study. Technical aspects are also only briefly discussed. Therefore, the topic need further research in RFID in regards of these aspects.

Practical Implications

For practitioners, this research has showed how a Norwegian pipe manufacturer can apply00 RFID to their production facility to solve some of their challenges. The research also show how RFID technology can create new opportunities for companies. The study has also highlighted the major benefits and drawbacks to RFID-technology, illustrating the major decisions that has to be assessed when considering RFID.

Originality/Value

The originality of this research is that it addresses the gap in literature where it was identified a need for more research in the application of RFID in facility process management. It also provide a real life example of how RFID can be used.

Keywords

Radio frequency identification; RFID; Auto-ID; Production Control

Preface

As a part of the Master of Science program at the Norwegian University of Science and Technology (NTNU), the student are required to write a master thesis in which account for 30 credits. This master thesis was carried out by stud. techn. Sondre Sivesind Melbye at the Department of Mechanical and Industrial Engineering, as a part of the two-year master program Global Manufacturing Management (GMM) with specialization on production management.

First, I would like to thank NTNU, and my supervisor Jan Ola Strandhagen for making it possible for me to write this thesis. I am grateful for all your interesting lecturers during my time at GMM, and for sharing your valuable knowledge.

I would also like to give a huge thank you to my co-supervisor Jo Strandhagen for all the valuable input and guidance through the project work. This thesis would not have been the same without it.

I am also grateful to Pipelife for being part of this study, letting me see their production facility, giving me a tour, and being available for interviews.

Thank you to all my co-students for all the good times you have given me, and for making the time at NTNU a valuable and ever lasting memory.

The final thank you have to be given to my dear Susanne for keeping up with me during a busy and challenging time of my studies. Your support and help mean the world to me, and has given me the spirit to keep going and get this done. I love you.

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1 Introduction

In this chapter, the master thesis will be introduced by a presentation of the subject and the problem in which it addresses. The chapter present both a theoretical problem, identified by a gap in the literature, and a practical problem based on the present challenges identified in the Norwegian industry and the production facility of Pipelife Norge AS located in Surnadal (hereby referred to as Pipelife).

1.1 Background and Justification

With increasing globalization comes more international companies to Norway, and the markets where Norwegian companies are present. Keeping production domestically is important for Norway since it would mean retaining knowledge, creating or sustaining work places, and creates a short distance from production to research and development (R&D) activities. As stated by Ministry of Trade, Industry and Fisheries (2017): *"increased globalization has moved jobs from traditionally industrial countries to more emerging economies where the cost-level is lower"*. The importance of retaining production domestically is shown by the claim of Ministry of Trade, Industry and Fisheries (2017) that Norway's ability to innovate has been reduced following the relocation of job to low-cost countries. For companies to be able to keep production domestically, they must find ways to compete against international competitors with different boundaries.

In Norwegian manufacturing, where labor costs are high, there is a need for reducing costs due to increasing competition from companies located in countries with lower labor cost level. As well, Norway is a country characterized by a high technological level, in which could be the source of a new, improved competitive advantage for Norwegian companies. A high technology level is likely to ease implementation of new technologies due to a good infrastructural foundation, and a high understanding of technology by the Norwegian labor force. Although Norway can be seen as a country with a high technological level, there are still large potentials for digitalization. Ministry of Trade, Industry and Fisheries (2017) states that only 17 % of Norwegian companies are advanced users of digitized and automated production. A more digitalized production and control, may reduce the impact of wages to the competitiveness of a company in that manual tasks are made more effective, or replaced by automated processes.

The world market is in constant change, facing trends like globalization and increased global competition. Digitalization is a buzz-word in the current times and many companies seek to explore this concept. Large focus on ICT development has created opportunities for new business models and new strategies for achieving competitive advantage in the new, globalized market. As stated by Musa & Dabo (2016): *"ICTs allow organizations to continuously improve their responsiveness and competitiveness by adapting their operations strategies, methods, and technologies to near-real-time data at the Enterprise edge"*. By real-time, the definition by Arica & Powell (2014) is used: *"Real-time information capture is the capability of obtaining the required information at the required time from the intended objects, devices or people by data capturing technologies"*.

For manufacturers, change is a daily challenge. Whether it is demand, resources (for example machine breakdown or employee absence), or other changes. Early identification of such changes will allow for faster dealing of the emerging challenge. This justifies a larger focus on monitoring of production and resources. Achieving monitoring in real time, i.e. getting information about changes as they are discovered, will give manufacturers the best foundation on which control is preformed. Porter (2008) states that *"information creates a new way businesses can outperform their rivals, and spawns new businesses"*. It is in this area ICT and emerging technologies can play a part. Technologies that can enable information capture in real-time are Auto-ID technologies. These technologies will, through digitalization of manual tasks, both support the need for reduction of labor costs and present methods for automatic capturing of information.

There are five types of auto-id technologies: Quick Response (QR), Barcode, RFID, Biometric systems, and smart card (Flanagan et al., 2014). According to Flanagan et al. (2014), the competition among the different Auto-ID technologies are practically between barcode and RFID. They offer the greatest value in terms of options and price. Here, RFID seem to get the slight edge due to its superior automation features compared to barcode. Although, the barcode technology is cheaper, in which may better justify the business case on barcode compared to RFID. But in recent years, the price for the RFID tags has went down, making the technology cheaper and the business case better. RFID as a technology is not new to the world. In fact, there are roots of the system all the way back to the Second World War (Flanagan et al., 2014). However, in the area of facility process management, the technology is not as commonly applied. Therefore, with all the advantages RFID gives, the possibilities of RFID deserves to be more looked into in the area of manufacturing.

Based on the information given above, there is a need for exploring digitalization in Norwegian companies which are facing increasing global competition. A technology that can support this goal is Radio Frequency Identification. This research will address the need for digitalization, and the gap in literature in which are lack of research on RFID in facility process management. The objective of this research is to explore the benefits and drawbacks of RFID, and how RFID can be used in Norwegian manufacturing. This research will do so by illustrating how a Norwegian company can benefit from the identified benefits in production control.

1.2 Problem Definition

Following, the justification for doing this research is given with the theoretical and practical problems, as well as how it may contribute to knowledge.

1.2.1 Practical Problem

As a part of their strategic focus on smart manufacturing, Pipelife has participated in the ManuNet 4.0 project [1] - iKuben.no (2015). During this participation their factory in Surnadal has been subject for observation and analysis, and some challenges has been discovered. In Surnadal there were identified challenges related to inventory accuracy, tracking and tracing of products, and the flow of materials and information. These challenges affect the performance of purchasing, inbound logistics and the production at Pipelife Surnadal. These activities are all core in a company where two of them (Inbound logistics and Production) is considered core activities, and purchasing is considered a supporting

[1]"The R&D-project Manufacturing Network 4.0, initiated by iKuben, is a competence project for businesses, owned by Molde University College and NTNU. The project is about the importance of manufacturing expertise for long-term innovation capability"

activity (Porter, 1985). Thus, the sub-optimal performance in these activities directly influences the margin and competitive advantage of Pipelife.

The challenges related to inventory accuracy express incorrect needs and lead to incorrect volumes being purchased. This can then lead to stock-outs or an overfilled storage. Stock-outs can for example affect the production and result in delays, unplanned down time, and decreased customer service level. On the other hand, unnecessary high storage volumes will increase holding costs.

There are also large volumes of products and intermediate products being transported and handled within the production facility yearly. There takes both time and effort to keep track of, and coordinate these products and their flow. Sub-optimal tracking systems can lead to time being spent on looking for articles or equipment in stead of value adding activities such as production. Thus, having a well functioning system for tracking and tracing products within the facility may reduce time spend on undesirable activities, and even improve the productivity of the production.

To deal with these challenges, Pipelife has expressed an interest to explore the opportunities within Auto-ID technologies.

1.2.2 Theoretical Problem

RFID has been researched for a long time, and in many different application areas. It has been researched in inventory management, process optimization, and life-cycle management. Approaches like exploring the impacts of RFID across the whole value chain, not only in integral operations, has been presented by Ngai et al. (2008). In 2008, most (80%) of the literature on RFID consider technical aspects, and there is a need for further analysis of business issues (Ngai et al., 2008).

Newer research, such as Musa & Dabo (2016) states the need for exploring how RFID can be integrated with legacy systems (current/older systems). There are also considered a lack of studies in real life implementations. Much of the research is tested in small test facilities, or only in simulated environments. In the literature review presented by

Musa & Dabo (2016), it was also discovered that little research had been focusing on factory process management. Only as much as 38 articles had this focus the previous 15 years. Factory process management includes the development of monitoring systems for visibility and control of factory processes and models for production planning and scheduling (Musa & Dabo, 2016).

1.2.3 Contribution to Knowledge

This research will contribute to knowledge in that it explores business issues related to RFID and the use of RFID in the factory process management, research areas in which has lacked attention previously. It should use the technical work of previous studies, and adopt it to a contemporary case, contributing to researching how RFID can be applied in a real-life scenario. In a practical way, it should aid in understanding the benefits in which RFID will bring and the cost that is related to an implementation of an RFID system. It should also be a basis for decision making for practitioners seeking to apply RFID to their production. It is mostly focused to companies following a make-to-stock strategy in a similar environment in which Pipelife is present.

1.3 Research Aim

Several authors present several benefits of RFID technology (Sarac et al., 2010; Ngai et al., 2008; Musa & Dabo, 2016). These benefits include improved traceability and visibility of products, improvements on information accuracy, and facilitation of management through real-time information. If realized, these benefits should be able to reduce the challenges seen at Pipelife. Based on this, RFID is worth investigating in relation to this research. Therefore, the research aim is selected as:

Investigate how RFID technology can support production control, and how an RFID system can benefit Pipelife

1.3.1 Research Questions

For the selected research aim, there can be several approaches. To guide the research in the desired direction, a set of four research questions has been derived. These are the elements of this study that has been selected as interesting to research, and which will provide the foundation on which the research aim will be concluded.

1. What are the main benefits and challenges to RFID technology?
2. How can RFID technology support real-time decision making?
3. How can RFID technology impact production control at Pipelife?
4. How can an RFID system be designed to fit Pipelife?

1.4 Scope of Work

The object of this study will be the Pipelife's manufacturing facility located in Surnadal. There are several areas in the facility producing different products with varying product characteristics. This study will focus on the area in which customized products are made, hereby labeled the Crafting Department. This department produce products in which are not standard products with dedicated production lines within the facility. Such products are bent pipes and customized chambers.

This research will look into the internal material- and information flow related to production control at Pipelife, and the use of Radio Frequency Identification (RFID) technology. In this research, the RFID technology itself is not the object for discussion, rather how RFID can be applied. Hence, the RFID data is what is interesting.

1.5 Limitations of the Research

In order to define the full scope of the research, it is important to consider the limitations of the study, as well as what has been done. This section will sum up the most important limitations in which has been recognized.

Time

The master thesis has a predetermined length of 20 weeks (+1 due to the Easter holiday). This limit the extent of field research and testing that is achievable. The time constraint also limit the scope, as the extensiveness of the study has to be limited. With more time, a deeper and more comprehensive study can be achieved.

Literature

Even if a structured literature search is conducted, there is a chance of missing out on important literature. This is caused by many different databases being used by researchers, and due to many articles being in languages in which the author cannot read. The literature is also limited to what is available at the NTNU library, and databases in which NTNU-students have access to.

Research design and focus

The research focus on how the RFID data, and an RFID system, can provide value and cost savings. However, purely human and technical aspects has not been considered. In addition, the main focus is on the internal flow of materials and information. There may be significant external factors which should be considered that will not be captured in this research. Lastly,this research do only consider a single case. Comparisons of several systems would therefore be impossible and is recognized as a weakness.

1.6 Thesis Structure

The structure of the thesis will be based on the IMRaD structure: Introduction, Methodology, Results and Analysis, Discussion and Conclusion. Though, there will also be a chapter presenting the case company before the results chapter.

The following chapters are structured as this. Chapter two presents the methodology applied in this research, together with the methods used and the methodical limitations of the study. Chapter three present the theory on RFID. The case company is presented in chapter four, and in chapter five the proposed system design is presented and elaborated. In chapter six the design and its implications are is discussed, and chapter seven concludes the research. The structure is illustrated in figure 1 with the solid lines showing main input to each section, and the dotted lines showing additional input to the section.

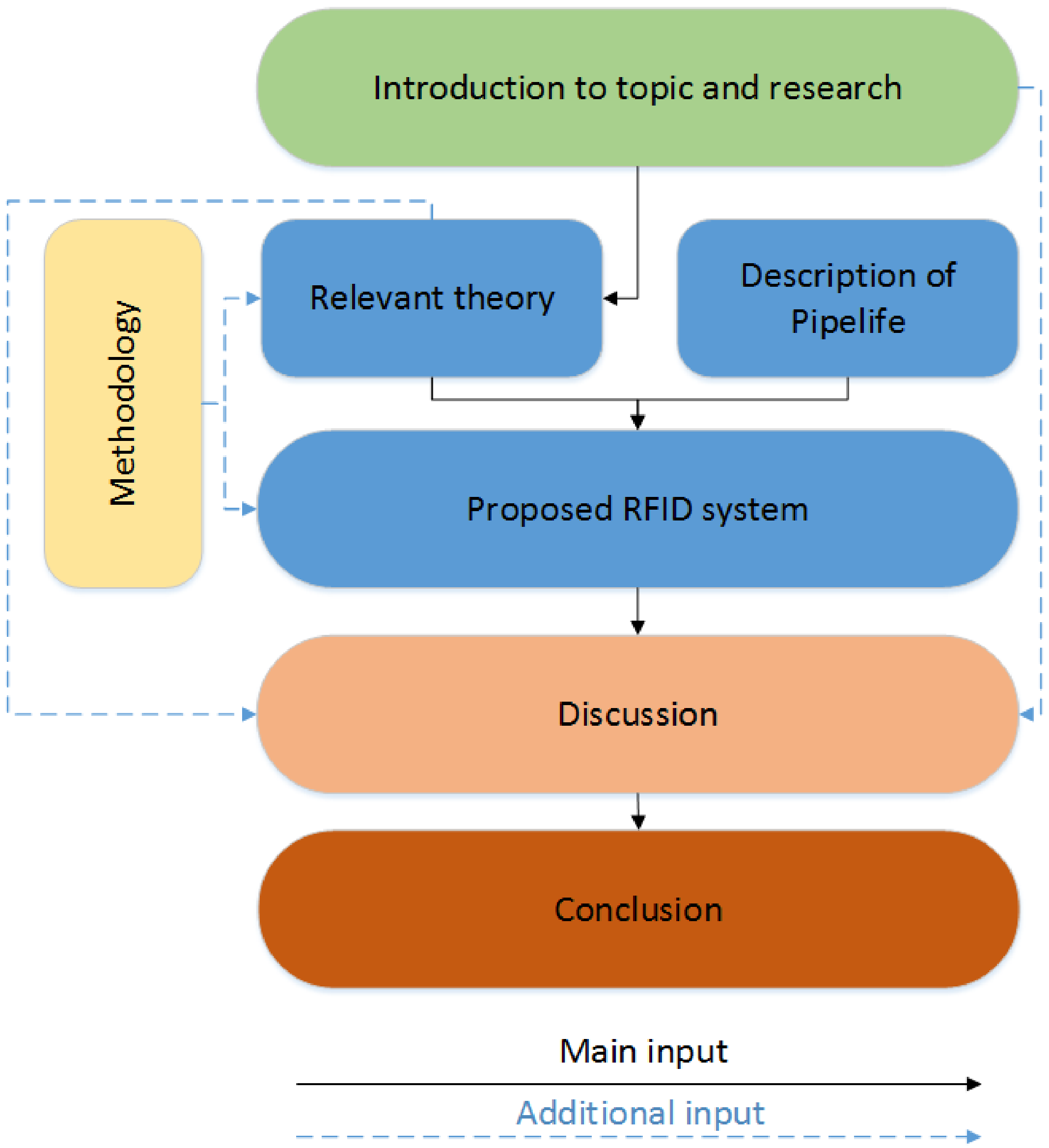

Figure 1: Structure of the Thesis

2 Research Methodology

This section will present the methodology selected for this research. The used methods will also be elaborated upon and discussed. Strengths and weaknesses of the research methodology will mentioned where it is applicable. Finally, a more detailed description of the process is given in order to ensure repeatability of the study.

2.1 Chosen Methodology and Research Design

The research will be following a design science research (DSR) strategy, in which is accompanied by methods such as interview and case study. The research strategy is *"aimed at knowledge that can be used in an instrumental way to design and implement actions, processes or systems to achieve desired outcomes in practice."* -van Aken et al. (2016). According to van Aken et al. (2016), DSR is driven by field problems or opportunities. This research is focused around the problems found at the Pipelife factory, and their strategy "Smart Factory / Smart Manufacturing". In relation to this, a desire to look into the opportunity of tracking technology, for example RFID, has been expressed.

"DSR focuses on improving the present" - van Aken et al. (2016)

The study is designed according to the suggestions by Hevner (2007), and based on the three design science research cycles. First, the relevance cycle puts the research into a real life context. The requirements for research are identified in this cycle, and hence the evaluation criteria. The relevance cycle is also where the field testing is done, and the testing determines whether more iterations of the cycle is needed. This research will utilize the relevance cycle to bring the context to the research, and will hence present the first iteration of the cycle. Second, the rigour cycle is where former knowledge is introduced to the research. The rigour cycle aims at guaranteeing that the produced designs contributes to knowledge. In the central position the third cycle is found, the design cycle. It is *"the heart of any design science research project"* (Hevner, 2007). In the design cycle, the activities of creating and evaluating the design artifact are performed. However, it is important to ground this in the cycles beside it: context and knowledge. The design of this study is illustrated in figure 2.

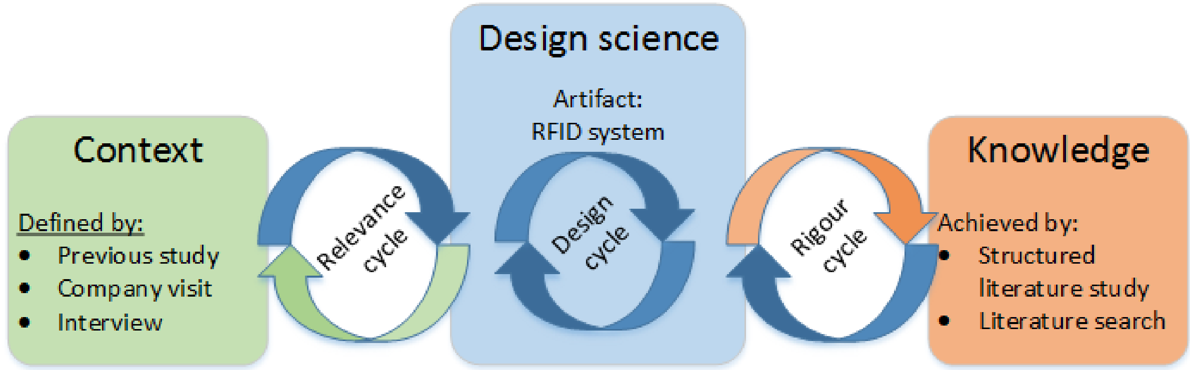

Figure 2: Research Design

2.1.1 Design Science Research

Design science research consist of two components, the descriptive, explanatory component and the design science component. The descriptive part is where the problem type, causes and context is analyzed. The Design part is where a generic design is created/designed by design-testing-redesign-cycles. These phases should not be considered separate and chronological. In fact, it is important to early in the process start sketching possible design ideas to gain insight to guide the explanatory phase in terms of what knowledge is necessary to obtain. However, in this research the first part will be the major focus due to the limited options to field testing.

"DSR takes the perspective of the involved actors seeking to improve matters" - van Aken et al. (2016)

The core product of design science research is the generic design van Aken et al. (2016). The generic design should be well tested, well understood and well documented, as well as field tested to ensure its pragmatic validity. That is that the desired outcomes is achieved. This generic design is supported by design propositions to suggest how and where the generic design can be used. The design proposition follows the CIMO logic, as described by van Aken et al. (2016) as *"For this problem-in-Context it is useful to use this Intervention, which will produce through these Mechanisms this Outcome"*. Though, the generic design is the core product, it is not the only. There are also other outcomes of DSR such as fundamentally new approaches to a certain issue or a methodological innovation (ex. approaches for field testing generic designs in volatile environments). Action research and Evaluation is considered similar research methods as DSR. The validity of DSR focus on effectiveness, that the desired outcome is achieved. As van Aken et al. (2016) puts it: *"Does the realized design work?"*.

DSR is easiest applied in purely mechanical systems, not dealing with social components (ex. human behaviour). Hence, when a system contains social components there are some challenges occurring. Some of these are the collecting of evidence on pragmatic validity and the generalization of the design. This is due to what can be labeled *strong-* and *weak mechanisms*. Strong mechanisms are mechanisms in the material domain that are invariant and universal that determine behaviour and linking causes-effects and action-outcomes (van Aken et al., 2016). The weak mechanisms is found in the social domain where the mechanisms are not invariant nor universal. These mechanisms influence, but does not determine the human behaviour such as strong mechanisms do. This challenges the ability to predict with certainty the performance and behaviour of the system, affecting the pragmatic validity. This also affect the ability to generalize the system as the human behaviour is often context-specific.

The first component of DSR, explanatory research, does focus on truth, whereas the second component is focused on the future effectiveness of the system (or process). This will be solved through a literature study (first component) and by creating a system and drawing generalized conclusions (second component). According to van Aken et al. (2016), a generic design is *"a design that can be transferred to contexts other than the ones in which it has been made and tested without loosing its basic effectiveness"*. As earlier touched upon, the generalization of the design is affected by the amount of social and mechanical factors in the system. Systems with high amounts of social components is more difficult to generalize due to its less tangible mechanisms compared to systems with a higher degree of mechanical components. A method to help in generalizing systems with very case specific variations is, according to van Aken et al. (2016) to test the system in a several cases and to do cross-case analysis. However, this research only include one case and it is therefore impossible to follow this suggestion.

Operational issues

van Aken et al. (2016) introduce the three operational issues of the design science approach: the components of DSR, field testing, and determining mechanisms that generate outcomes. Design testing is, as mentioned earlier, a key part of DSR. Testing creates the foundation on which the scientific rigour of the research is determined, i.e. quality of the research. It is though testing the researcher discovers if the system generate desired outcomes. In addition to the testing itself, documentation of it is important. This to explain the role of the researcher and to prove the objectivity of the testing (van Aken et al., 2016).

In this research, there are no physical testing of the system, which is assessed as one of the major weaknesses of this research. Though, the validation through interview and feedback will establish the practicality of the design, and valuable insight to the design. This way ensures a thorough design where practical aspects is considered before any implementation. Hence, the system should encounter less troubles when implemented.

2.2 Quality of the Research

To ensure the quality of the research, the following four elements has been considered:

- Construct Validity
- Internal Validity
- External Validity
- Reliability

Karlsson (2009) and Yin (2014) both states the importance of these factors. First, to ensure construct validity, all measures used in this research are carefully selected in order to get the desired results. A tactic to ensure construct validity is establishing a *chain of evidence* (Yin, 2014). In addition, as presented by van Aken et al. (2016), the strength of the DSR is determined by its construct validity, i.e. "how well the system works". Therefore, a part of the quality assessment could be determined by the performance of the system.

Internal validity is mostly a concern for explanatory studies where the researcher seek to find out if x lead to y (Yin, 2014). In case studies the internal validity is mainly about inferences and occurs whenever an event cannot be directly observed. Some measures to ensure internal validity is to do explanation building or to address rival explanations. In this study, very little of the challenges has been directly observed by the author, and can therefore be treated as a weakness to this study.

External validity concern itself of the applicability of the results outside of the study. In other terms, generalization of the results. This is ensured by using basic concepts that is relevant for companies with similar characteristics. Yin (2014) argues that forming the research questions can affect ability of the study to seek generalizations. Therefore, a great attention has been given to formulating good research questions with the motive of external validity in mind. The design science research approach is suitable for ensuring external validity as the generic design is the core outcome. However, when dealing with systems influenced by human interaction, this generic design can be difficult to obtain. Hence, the external validity can be a challenge to ensure.

To make sure the study is reliable, the author has been particularly careful of using conclusions and arguments that is founded in the research and the theory, and not affected by any personal bias or subjective opinions. Reliability is also achieved by carefully describing the methodology and the steps taken during the research.

Lastly, Karlsson (2009) states that the value of the research is also part of determining its quality. Therefore, it is aimed to select a topic with both high practical relevance and theoretical contribution.

2.3 Methods Used in the Research

Method, according to Karlsson (2009), *"refers to the technique of data collection and analysis rather than the interpretation of empirical findings"*. Hence, there are several methods that may be used in a selected methodology. Some of the most common methods are: Survey research, case research, action research and Quasi-experiments. In this research, the data collection will be done using literature found through a structured literature study, some supplementary articles and books, interviews and visits to the factory for observations and dialogue.

2.3.1 Literature Study

The literature study was conducted in two steps. In order to establish context and background to the topic a preliminary literature search was done. When research aim and scope was decided, a more thorough study had to be done. This was done following a structured literature study approach. The two processes are described next:

Preliminary Literature Search

The first literature search was done using the Scopus database, searching for "RFID Literature review". This search resulted in 206 hits, where the most cited relevant articles was selected for analyzing the status of RFID in the supply chain. This formed the basis for stating the purpose of this study in term of the gap in theory.

Structured Literature Study

The structured literature study is performed to create the first component of DSR, explanatory research. By doing this, the state-of-the-art research in the area is assessed, and the system design should be based on the result from this.

> *"A fundamental part of any academic research is to review the existing academic literature in the field of interest" - Karlsson (2009).*

The structured literature study has been conducted following the approach described below:

1. *Select databases*

   Scopus was selected as the database used for the literature study. This database includes mostly peer reviewed articles, and is not open source. When doing the search, an acceptable amount of hits were achieved, therefore no other databases were used.

2. *Search using search strings*

   Based on the results from preliminary literature search and discussions with co-supervisor, the search string was created in order to capture the most relevant articles in the area of research.

3. *Selection criteria*

   All matches of the search may not be relevant, therefore a set of criteria on which ones to include need to be formulated. A set of criteria was formulated as presented below. If yes is the answer to the criterion, the article should be included.

   (a) Not older than 10 years?

   (b) Journal Article?

   (c) Title show clear relevance?

   (d) Abstract Show clear focus on the selected topic?

   (e) Conclusion and table of contents show clear focus on the selected topic?

   (f) Full Article show clear focus on selected topic?

   Since technology advances happen rapidly using old articles may result in incorrect facts and conclusions. Therefore, it was decided to only include articles newer than 10 years. Even 10 years may be a bit too old, therefore the content need to be compared to newer articles for confirmation and justification. Then, the articles was filtered to only include articles, articles in press, and reviews. This was to ensure only reviewed articles is included, and was done to ensure the quality of the literature review. The titles and the articles was then reviewed to ensure a clear relevance to the topic. The next thing was to look at the table of contents and conclusions of the remaining papers. Only papers that had a clear relevance to the topic and the industry were selected. The final process were to read the whole article and establish the final set of papers that is included in the literature study. The exclusion process is presented in table 3.

4. *Synthesis*

   The final part of the literature study was to analyze the articles that has been selected to extract the main results and findings that can contribute to this research.

2.3.2 Qualitative Interview

In order to get first person empirical data, interviews were conducted face-to-face during the company visit at Pipelife. The interviews were conducted as semi-structured interviews which is a qualitative interview method and well suited for this type of research.

#	Filtering type	Start	End	Excluded
1	Language	260	237	23
2	Year	237	153	84
3	Type	153	69	84
4	Title	69	64	5
5	Full text available	64	48	16
6	Abstract relevance	48	40	8
7	Table of content and conclusion relevance	40	38	2
8	Full text relevance	38	20	18

Table 1: Literature Study Exclusion Process

Semi-structured interviews are interviews where the questions are predetermined, but the interview itself unfolds in a conversational manner where there are room for exploring important issues (Clifford et al., 2016).

To be able to ask follow-up questions and to not be bound into typing while doing the interview, it was decided to record the interviews and transcribe them from the recording. This also allowed for a higher level of interaction between the interviewer and the interviewee.

Clifford et al. (2016) elaborates on the importance of the sequence of the questions asked, where sensitive questions should be asked in the second half of the interview. This was not assessed beforehand, and can therefore be considered a weakness to the interview. Making the interviewee feel comfortable is also important and should be considered in order to get a natural flow of the interview. The interview was conducted at Pipelifes' own location, therefore the familiar environment for the interviewees were considered as sufficient to make them comfortable in the interview setting. Looking back on the questions, there is room for more open questions to get broader answers and to cover a larger spectre of the topic

Both interviews can be found in Appendix A.

2.3.3 Production Control Model

When doing improvements or changes, it is important to create a shared understanding for all people involved. A Production Control Model is an abstraction of a company showing how manufacturing and logistics are organized and controlled (Alfnes & Strandhagen, 2000). Thus, the production control model is a good tool to generate the common understanding. The production control model method will be used to illustrate both the current situation (AS-IS), and the future state situation (TO-BE).

Mainly then control model way of illustrating processes and flows will be taken from the methodology, not all the steps included. There are more analytically steps, focusing on certain aspects of the production, these will not be followed as should be if following the control model methodology.

2.4 How the Study was Conducted

This study will be following the seven steps of the research process, as presented by Karlsson (2009)(Adopted from Croom, 2008):

1. Identify broad area of research
2. Select research topic
3. Decide the approach
4. Formulate the plan
5. Collect the data or information
6. Analyze and interpret the data
7. Present the findings

Though, the research process is not necessarily following this chronologically as research is iterative in its nature (Karlsson, 2009; Yin, 2014). Topic and background was stated from the beginning, but research questions and methods is revised regularly in order to ensure a precise research and that the most applicable methods is used for data collection and other things.

The broad area of research was identified to be Digitalization. This was based on the authors previous work and interests. The research topic was also partly decided based on previous work of the author, but also due to a given problem description and desire by the case company. Tracking technologies (or Auto-ID) technologies was then selected as a narrowed scope.

As there was a case company interested in this issue, it was early very likely that the research would take the approach of a case study or an action research study. A similar approach of the action research, but not as commonly used is the Design Science Research. According to the arguments given above, the DSR approach was selected.

Then a plan had to be created on how to conduct the research, and it was decided to perform interviews as the main source of empirical data. Second, it was decided to use a structured literature study to capture the up-to-date state of RFID technology research. The study design is illustrated in figure 2.

As mentioned, data was collected through interview and a literature study. Also some separate sources was used for contextual purposes. Data was then analyzed, and the theory is presented in chapter 3. The results and findings are presented in chapter 5 of this research.

3 Theory

In this section, the theory related to the research will be presented. First the theory on RFID is presented with describing a generic RFID system, before the results from the literature study is given. This results are presented chronologically, with the oldest research first. This part in the summed up in the end. The production control model is briefly presented in the final part of this section.

"Theory is an attempt to explain how a system or phenomenon works by identifying the constituent elements of the system and how they interact and relate to each other" - Karlsson (2009)

Theory consist of a collection of logically interrelated propositions that aim to explain a set of phenomena (Karlsson, 2009). A proposition is a statement in which some relationship between two or more concepts or variables is proposed (Karlsson, 2009)), typically in the form of declarative statements, bivariate or multivariate. A law is a proposition about which we have sufficient evidence to believe that it is probably true.

A hypotheses are propositions that state a predicted or assumed relationship between two or more variables. A hypothesis must be stated in a way that it is possible to be tested through field research. Hypotheses must be stated in a way that it answers the problem statement.

3.1 Radio Frequency Identification

First, the concept of RFID should be presented in the following paragraphs. This section will then present the theory on Radio frequency identification found through the literature study. The section is presented chronologically, where the oldest paper is presented first and the newest last. Where the year of publication is similar, the papers are presented alphabetical.

Radio Frequency Identification, RFID for short, is an automatic identification and data capture technology that is composed of a transponder (a tag), a transceiver (a reader), and a middle-ware system for data processing (Musa & Dabo, 2016; Liu et al., 2009; Chen et al., 2012).

RFID tags can again be categorized into three types, active, passive, and semi-passive (Visich et al., 2009). The difference is whether or not the tag posses an internal battery or not. A passive tag does not include an internal battery, and is powered by the waves emitted from the reader. These tags have limited signal strength, hence also range(Chen et al., 2012). Semi-passive tags does include an internal battery, but still require power from the reader to function. However, they are suited to store and monitor information. Active tags is self sufficient and does not rely on powering form the reader. Active tags does also have higher signal strength and can emit signals up to about 30 meters according to Chen et al. (2012). Arkan & Van Landeghem (2013) argues active readers may broadcast signals as far as 100m. Furthermore, RFID tags can be chip-based or chip-less. The chip does allow for storing data and integration of other elements such as coiled antennas for RFID communication. Chip-less are on the other hand cheaper. The chips can be read-only with a pre-programmed information or read/write that allow for changing of the data and overwriting (Visich et al., 2009).
There are numerous papers on RFID considering a wide area of application areas, industries, and business focuses. For older literature reviews see for example Ngai et al. (2008) or Sarac et al. (2010).

3.1.1 Literature study

Liu et al. (2009) did investigate the use of RFID in the integrated-circuit assembly industry in Taiwan. RFID is here used in combination with a RosettaNet[2] network and an ERP-system, and integrated by creating a electronic material flow control system. The system was applied to a wafer-receiving and material inventory transactions as they were identified as the most labor-intensive and erratic operations. Through its system, Liu et al. (2009) were able to reduce total transaction time per season from 1200 to 120 min, as well as reduce the client's complaints to zero. For inventory transactions, there was identified improvements in six areas: Request generation, record processing, item-picking request generation, item-picking record processing, report generation and internal com-

[2]RosettaNet is a business protocol that overcomes the barriers to business over the Internet by establishing a global language for e-business (Liu et al., 2009)

plaints. Hence, Liu et al. (2009) proved how integrating RFID, and a RosettaNet network into the assembly process could increase the capability of the ERP system. The system does not include RFID only, but as Liu et al. (2009) puts it: *"RFID can move beyond merely an automatic identification technology to play a key role in holding information of value to works"*. Drawbacks to RFID was identified as signal interference and barriers of the signal such as extreme heat, metals and strong radio frequencies.

Visich et al. (2009) on the other hand, explored the RFID impacts on supply chain performance. Visich et al. (2009) states benefits to RFID has been identified to improved accuracy of information sharing, reduced storage, handling and distribution expenses, and increased sales through reduced stock outs, increased customer service and satisfaction, increased collaboration and planning. Namely, a great deal of benefits can be found, but there are also significant limitations. Lack of ROI, costs, and no lack of support was found as concerns during a survey from 2004 (Visich et al., 2009). Limitations also include environmental impacts and security.

Through a literature study, Visich et al. (2009) presented a framework of metrics on which RFID can be evaluated empirically. The metrics are illustrated in table 2. Of the identified beneficial effects within operational processes, most of the benefits was found to be automational. That is, value achieved from making processes more efficient. A major automational effect is the how RFID can lead to the need of no manual shelf inspections and automatic triggering of shelf replenishment. Among the automational benefits in the area of inventory control, Visich et al. (2009) presented several results where inventory count accuracy was increased to reach above 99% accuracy, reduced inventory, and product locating accuracy of 99.9%.

Informational effects, the value generated from the ability to gather, store, process and distribute information, is more limited, but a reason for that may be the difficulty of quantifying the benefits if informational gains. But again, information is also part of automational effects, such as locating inventory and counting inventory. Within managerial processes, the benefits was found to be merely informational and include results such as annual procurement cost reduction of 11 % and production planning accuracy

	Automational	Informational	Transformational
Operational *(Focus on efficiency)*	Labour cost Reliability Efficiency Inventory costs Throughput	Utilization Quality Responsiveness Waste Operational flexibility	Product and service Innovation Cycle times Customer relationships
Management *(Focus on effective decision making)*	Administrative expense Control Reporting Routinization	Effectiveness Decision quality Empowerment Creativity Resource usage	Competitive flexibility Competitive capability Organizational form

Table 2: Business Value Metrics (Visich et al., 2009)

improvement of 29 %. The study also confirms the statement made by Mooney et al. (1996): *IT impacts on business value is firstly automational on operational processes due to automation of certain processes and informational on managerial processes resulting from the availability of better information for control, coordination and decision-making.*

Visich et al. (2009) show that the effects of RFID implementation can be quantified and to be used in ROI-analyses and to build the business case for implementing RFID. Though, it should be carefully stated that these improvements does not necessarily come from RFID implementation alone.

For inventory management, RFID can be used to monitor and control inventory (Visich et al., 2009). This include monitoring and control of the reception of raw materials, transportation of raw materials into the production facility or point of use, movement of work-in-progress (WIP) inventory, and transportation and storage of finished goods (FG). It can also be used to signal the need for replenishment.

Although benefits may be several, there are also drawback to RFID technology. Visich et al. (2009) separates these into technical challenges and organizational challenges. Technical challenges include the dependability on layout and equipment. For example, ensuring reading of the correct RFID tag can be challenging. Also placement of the readers can be challenging as they need to be put in areas where they are likely to not be damaged or interfere with each other. As well, materials such as metal can limit the ability to read the tags. Organizational challenges is much about the implementation of the system. It is important to gain acceptance from employees and educate them in the system, as well as defining the requirements of the system in terms of how it should work (Visich et al., 2009).

Chen et al. (2012) takes on the perspective of RFID and lean when they incorporates value stream mapping (VSM) and RFID into a facility monitoring system. RFID is here used to ensure that the monitoring system is real-time and that it can simultaneously monitor multiple products. The result is a real-time VSM that can illustrate the real situation on the shop floor. The system manages transmit real data to the software platform, to generate a real-time online VSM that is able to present average lead-time and transportation time, and to track flow of multiple products. Chen et al. (2012) uses this system to determine how production in a job-shop layout compares to a cellular layout with an applied Kanban-system [3]. This show how RFID, in combination with the VSM-method, can assist in validation of layout design and to measure performance of workstations and process flow.

According to Majrouhi Sardroud (2012) there are five major forms of auto-id technologies: Barcode systems, RFID systems, smartcards, biometric systems and optical character recognition. When choosing a technology the following variables, among others, should be considered: affordability, ease of use, data storage capacity, read range, and life expectancy.

Qu et al. (2012) present an approach for creating an RFID enabled shop floor. One must first create smart objects from the original objects. This is done in a two-step process: attach auto-ID tags to production materials, and then to equip value-adding manufacturing resources with auto-ID readers. This implies knowing what items should be converted into smart items, and knowing what manufacturing resources are adding value for the customer. This is for example stated by Qu et al. (2012) as the location where the state of material goes toward being finished product. Qu et al. (2012) also suggest that *"RFID*

[3] Kanban: Japanese and mean "signboard". Used for inventory management and production control

transponders should be attached to those object which are shipped or moved within a cycle and eventually returns to its point of origin. The second step is integrating the smart objects through RFID gateways in which are a system for only collecting and processing the RFID information. The third and final step is to create a application system (Qu et al., 2012). Such a system consist of visibility and traceability modules. The visibility module act like a graphical representation of a specific manufacturing site with real-time operation status, and the traceability module is there to enable coordinated processes and for analyses done afterwards (such as failure investigation). This system is, though, very process specific, and is likely to be customized for the company. Qu et al. (2012) showed that their system was able to be integrated to the case company's SAP-system.

Qu et al. (2012) experienced five managerial and operational benefits through their system: Adaptive decision, concurrent execution, real-time visibility and traceability, Batch transaction, and corporate image promotion. Adaptive decision is achieved through real-time feedback that closes the loop between planning and control. This can potentially improve quality and efficiency of material distribution. Effective information capturing and sharing does enable some processes to be performed at the same time, such as assembly operations and replenishment for assembly components. RFID readers are able to process multiple units, resulting in whole batches being able to be processed simultaneously (for example a pallet of products) in stead of one at the time. Finally, by implementing an RFID system, the company was further regarded as a hi-tech company. Challenges include change of working environment for the workers and the accuracy of the RFID readers, as well as the *three high problems* (high costs, high risk, and high technical threshold). Qu et al. (2012) argues small to medium sized companies cannot overcome these "high problems" by themselves, but require sharing of the problems.

In order for RFID technology to be adapted to the manufacturing environment, it has to be integrated through a real-time location system (RTLS) [4] (Arkan & Van Landeghem, 2013). Arkan & Van Landeghem (2013) validated the use of RFID in a quality control department to validate performance before and after layout redesign. According to

[4]RTLS is a system that locates objects automatically within a pre-defined area ans is able to monitor them in real-time (Arkan & Van Landeghem, 2013).

Arkan & Van Landeghem (2013): *"The facility layout has a significant impact on shop floor productivity"*. Therefore it is important to validate the layout performance, and through this study it is shown how RFID can be used to validate designs and to establish quantifiable measurements of redesigns. However, this would require performance measurements of the original layout as well. A challenge for RFID applications according to Arkan & Van Landeghem (2013), is the huge database capacity requirements and data cleaning times resulting from excessive data streams. Actions to mitigate this challenge is to reduce the data transmission rate, or to use a middle-ware system to process the raw data to get filtered data. In the case of Arkan & Van Landeghem (2013), they were able to identify a decrease of performance of the new layout compared to the old. That illustrates the importance of testing new designs before implementing, and that change is not entirely positive regardless. Using RFID in a RTLS and simulating new designs may therefore be a critical part of the process of determining a new layout.

RFID has also been combined with the lean philosophy, such as in Chen et al. (2013). Through a design process involving RFID, Value stream mapping (VSM), and validation through simulation, the system showed an improvement of 82% for item reception of pallets. The results showed that the majority of the improvement came from the lean implementation, but with RFID combined with lean as much as an additional 12 % were achieved. With RFID, warehouse management can reduce its manual process times and eliminate possible human errors, leading to higher throughput and lower labor cost. Much of this is resulting from RFIDs ability to read multiple items automatically, and not having to scan each single item. However, in the value adding activities RFID improves the system more than the lean implementation did.

Shamsuzzoha et al. (2013) compared RFID with barcode and QR code systems and the results showed a significant faster read time when using RFID (2,5 minutes compared to 22,5 minutes for QR and 6 minutes for barcode). The results stemmed from a simulated environment, and not a real-life scenario. However, many real-life like scenarios were created such as tags in different locations, dirty tags and different light conditions. At the same time, readers of barcode and QR has improved since this research was done. But at the same time the cost of RFID tags and readers has reduced and reading is getting more reliable (Tabanli & Ertay, 2013). Shamsuzzoha et al. (2013) states that RFID is the best technology, especially for large logistics providers with a high number of items to be read. With regards of cost effectiveness, the barcode can prove the superior solution of the system needs are covered by barcode.

Quantifying the benefits and creating an benefit-cost model is presented in Tabanli & Ertay (2013). They also point out the lack of successful real.life implementations on RFID. Similar to Chen et al. (2013), Tabanli & Ertay (2013) use the interface between RFID and lean when RFID is combined with Kanban and VSM. The value created from RFID can be divided into two parts: value related to production (decreased labour force and stock costs) and value related to customers (loyalty, satisfaction and income). The costs related to RFID can be summed up as hardware-, software-, and maintenance costs. A benefit-cost formula is derived based on the above mentioned benefits and costs. It is then tested in a automotive supplier company. The cost related to an RFID system including almost 4600 tags and three readers was estimated to just under 18 000 euros, where the readers constitute more than a third of the costs. However, by investing in this system is was observed several benefits in which resulted in a return time on the investment on approximately 20 months.

Zhong et al. (2013) use RFID as a major contributor to an advanced planning system. The real-time visibility feature that RFID enables is key for creating a planning system that can be adjusted to account for changes or occurrences such as machine breakdown. Its purpose is to collect real-time information and pass it to upper-level applications. Thus, RFID is creating a smart production environment where changes and disturbances can be tracked and traced. It also manages to coordinate decision making between different parties.

An interesting statement by Arica & Powell (2014), is that ERP systems alone cannot offer visibility into operational functions such as locations of products in the production process. This limit the systems' ability to support dynamic decision making. Generating real-time demand information is key to improve supply chain performance (Arica & Powell, 2014).

Zhang et al. (2014) introduces the term Internet of Manufacturing Things (IoMT). A system in which manufacturing things (operators, machines, materials etc.) can be embedded with sensors and interact with each other. In such an environment, the application of auto-ID technologies are investigated as a ubiquitous scheduling system are created. A key part of the system is to achieve real-time data, where RFID is a major contributor. Similarly, Zhong et al. (2014) consider scheduling and production planning using RFID. RFID technology is used to estimate standard operation times and dispatching rules. Here, Zhong et al. (2014) present a data mining approach of pre-generated RFID data. *"Auto-ID enabled data are not put much attention to, nevertheless, they carry significant knowlegde for supporting the production decision-making" - Zhong et al. (2014).* The system prepares, clean (of irrelevant and duplicate data), clusters, and analyzes the data. Such a system can aid in classifying and aggregation orders of different customers, as well as determining learning curves of the historical data.

In Guo et al. (2015), an RFID based intelligent decision support system for clothes manufacturing is created, in which RFID technology is integrated to capture real-time production information and remote monitoring of the production. To reduce investment costs on readers, Guo et al. (2015) attaches RFID readers to key- or bottleneck operations only. In this paper, RFID is preferred to barcode of two reasons: the short registration times that RFID offers compared to barcode, and that the RFID tag is reusable and more reliable than the barcode. The results of Guo et al. (2015) showed a 25% increase in production efficiency, 12% reduction in production waste, and 8% reduction of labor and system costs. lastly, the system show how RFID technology may support cloud manufacturing systems. Some success factors for system implementation was suggested as: a strong incentive policy for workers to accept the system, consistent commitment and support from both top management and workers, employee training of relevant personnel for efficient use of the system.

A set of RFID challenges is presented by Nayak et al. (2015). These include high cost, security and privacy issues, RFID attacks (i.e. tag damage, fake tag or hacking), compatibility, technology, and lack of standardization. Nayak et al. (2015) states that RFID should be used in systems where transaction speed is affecting the performance of the system. This is such systems where products are scanned in bulks. In term of security threat, RFID tags can in theory be read by any compatible reader, hence a security system need to be in place to keep any confidential information stored on the tags secure. Compatibility arises as a possible issue when integrating an RFID systems to legacy systems or external systems. This also brings the next challenge in to the light, technology. Companies are currently being skeptical to RFID due to the fast pace of technology and due to the possibility of emerging technologies outperforming RFID. The high investment may therefore be futile and costly. Finally, resulting from a large variety of RFID systems and software, there is a need for standardized systems to obtain the desired integration of systems.

Yang et al. (2015) present an approach to RFID where its real-time information acquisition and processing is adopted in a real-time manufacturing execution system (MES) for a mixed-model assembly process. A filtering approach is presented to limit the amount of unwanted information as input to the MES. This is done through layers of filtering. First a basic filter is applied to remove duplicates and redundant information. Then an advanced filter is applied in which analyze and classifies the data, and can then clean up any unreliable data. *"Reliable identification and tracking of manufacturing objects is the key to realize agile production management" - Yang et al. (2015).* That statement describe the importance of such a filtering system as explained above. Finally, a proposed model is presented to transition traditional-MES into a more real-time interactive MES.

RFID in relation to lean is revisited in Rafique et al. (2016). Through a structured literature search it is investigated how RFID aids in handling barriers to lean implementation. The major RFID benefits were illustrated as in figure 3. The barriers affecting lean implementation is classified into three different types: managerial, operational and financial. Managerial barriers mostly consider top management and employees attitude to lean implementation, as well as lack of skill. RFIDs ability to provide process visualization and asset tracking can help top management decision making, but also employees by an autonomous asset tracking system. Operational barriers include poor inventory control and longer lead times, in which result from improper handling of customer orders and schedul-

Figure 3: Major Benefits of RFID

ing. By providing real-time traceability and automated information visibility, RFID is able to improve both customer handling and inventory control, in which ultimately result in reduced lead-times. Rafique et al. (2016) even argues that handling of operational barriers also help reducing managerial barriers. Financial barriers are resource constraints, implementation costs, and lack of finances. Rafique et al. (2016) identifies studies in which has found RFID to be advantageous for cost effectiveness, in which can aid in reducing financial barriers.

RFID as a measure to reduce production costs in the steel industry is presented by Lee (2017). The vary nature of steel can be a challenge for RFID in term of interference. A type of tag was created to be able to tag steel beams. Such a tag, in the proposed system, was able to achieve 100% reading rate with temperatures changing from -20 to +200 degrees Celsius, and up to 2,5 meter.

Moon et al. (2018) present a self-developed system for efficient material tracking in the construction industry. Combined with WLAN and an RTLS, the system was able to provide real-time location services with precision within 1,27m-7,23m where most where within 4m. As well, by establishing the current wireless network (WLAN) as the communication platform, the existing infrastructure was utilized to reduce investment costs. The system performance was measured in the loading operation of scaffolding to a truck, and the results showed an performance increase of 11%. The performance increase was mainly due to the removal of the manual pre-arranging task.

3.1.2 Summary

This section will sum up the literature study on RFID technology. The major advantages and drawbacks are presented, as well as some comparisons to other similar technologies.

Among the selected papers, there was different research methods, industries, and RFID focus. There was several papers in which did not mainly and entirely focus on RFID, but where RFID was one of the key enabler to achieve the proposed system or architecture. This show the importance of RFID (or similar technologies) in order to create advanced systems capable of utilizing real-time information achieved from different operations from purchasing and logistics, to production and scheduling. Of the research methods, there were 11 of whom that applied the case study research methodology, being the most popular methodology. Case study research being popular may be a reason of the need of empirical validation of RFID in real life studies. However, many of these papers have a major part of theory, and only a lesser part of the actual case study. An overview of the applied research methodologies can be seen in table 3.

Research methodology	Amount
Case study	11
Literature review	4
Experiment	3
Other	2

Table 3: Applied Research Methodologies in the Literature

Advantages of RFID

The major benefit of RFID, and is mentioned in nearly all papers, is the ability to automatically capture RFID data in real time without requiring line-of-sight. This is the major enabler of other systems that are build on real-time data capture. It also allow for registration to be transferred from a manual task requiring manual labor, into an automatic task where no manual labor is required. With no line-of-sight required, it is possible to have the tag protected within a pallet or a box, hence eliminating the risk of tag damage and dirt (which can be a challenge barcode, for example). Lastly, RFID offers the feature to simultaneously register multiple products, enabling possible time savings in registration areas. A brief summary of mentioned benefits in the literature is presented below.

- Automatic reading of data / Identification (Chen et al., 2012; Arica & Powell, 2014)
- No line-of-sight required (Visich et al., 2009; Chen et al., 2012; Arica & Powell, 2014)
- Long reading distance (Chen et al., 2012)
- RFID more robust and not susceptible to damage or dirt (Visich et al., 2009)
- Simultaneously reading of multiple RFID tags (Visich et al., 2009; Yang et al., 2015)
- Read / Write capability and can carry more data (Visich et al., 2009; Arica & Powell, 2014; Yang et al., 2015)
- Affordability (Majrouhi Sardroud, 2012)

Challenges to RFID

Even if there are plenty of benefits to RFID, there are also drawback to the technology. Qu et al. (2012) presented the three "High problems" in which are high investment costs, high risk, and high technical threshold. An RFID system require investment in equipment, software, and personnel. The high risk of RFID lies in the rapid development of technologies, as there are a possibility that an emerging technologies will outperform RFID in the future. Implementing and using such an advanced system also require a high level of expertise to use it to its full benefits. It would also require a decent technological level among employees.

Strategic challenges	High investment cost High risk High technical threshold
Technical challenges	Interference Several programming languages

Table 4: Challenges to RFID Technology

In addition to these more strategic challenges, there are more technical challenges related to RFID technology. Different materials, for example steel, can cause signal interference and result in a poor performing system. There are also many kinds of RFID systems, in which are build in many different ways and languages. Thus, there is a need for standardizing how RFID systems are build to facilitate integration of several systems, both different RFID systems and other systems such as ERP systems. There are also challenges related to security and privacy, as well as practical problems such as damage to the tag.

Advantages beyond the scope of this research
This research does only consider a small part of the application areas in which RFID may be adapted. Benefits in these areas include, but are not limited to, RFIDs ability to support the closed-loop supply chain by enhancing reverse logistics and disassemble processes by holding information on salvageable parts (Visich et al., 2009). RFID may also benefit new product development in that it can store data on high-cost processes and provide traceability in real-time of new products.

3.1.3 Alternatives to RFID

In this section, a short elaboration on alternatives to RFID will be presented.

The first alternative is Barcode technology. As several of the authors states Barcode is the most realistic competitor to RFID. Many still use barcode due to its low costs compared with RFID. However, as presented by Visich et al. (2009): *"Compared with Barcode, the use of RFID tags can improve efficiency and provide higher level of information availability in identifying, processing and tracking goods as they move through the supply chain"*. In other terms, RFID offers far more features compared to Barcode, and when a company manages to take advantage of these, RFID should be the optimal choice (see table 5 for comparison between barcode and RFID technology). The main advantages of RFID over barcode technology are (Majrouhi Sardroud, 2012):

1. RFID is able to identify every item individually
2. RFID is capable of reading multiple tags simultaneously
3. RFID can hold more data and do not require line-of-sight.
4. RFID possess the feature of both reading and writing data
5. RFID tags are reusable, and more durable

A second alternative to RFID are biometric systems. However, biometric systems are mainly used for identification of humans and is not relevant in this research.The third alternative is Quick Response systems. These are very similar to barcode systems, but with a greater challenge related to security. Therefore, QR is also not considered in this study.

	Advantages	Disadvantages
Barcode	Affordable Easy to use Mature and proven technology Established quality standards Reliable and accurate	Optical line-of-sight scanning Limited visibility Restricted traceability Incapable of item level tracking Labour intensive Susceptible to environmental damage Prone to human error Limited memory
RFID	Non-line of sight scanning Simultaneously automatic reading Labour reduction Enhanced visibility and forecasting Item level tracking Traceable warranties Reliable and accurate Information rich Enhance security Robust and durable	Cost of tags and new infrastructure Lack of training and limited knowledge Immature technology Concern of return on investment Lack of ratified standards

Table 5: Advantages and Disadvantages of Barcode and RFID (Majrouhi Sardroud, 2012)

3.2 Production Planning and Control

Manufacturers are constantly making plans and schedules for future production. Plans are what are intended to happen in the future (Slack et al., 2010). However, changes happen unavoidably and to cope with this difference between the planned outcome and the actual outcome production control is needed. As put by Slack et al. (2010): *"Control makes the adjustments which allow the operation to achieve the objects that the plan has set, even when the assumptions on which the plan was based do not hold true"*. As the time horizon get shorter, the importance and significance of control is increasing. Short-term planning and control is based on dis-aggregated forecasts or actual demand, interventions to resources to correct deviations from plan, and ad hoc consideration of operation objectives

(Slack et al., 2010). Long-term planning and control determine objective from economic terms, use aggregated demand forecasts, and determines resources in aggregated forms. The significance of planning and control in relation to the time-horizon is illustrated in figure 4.

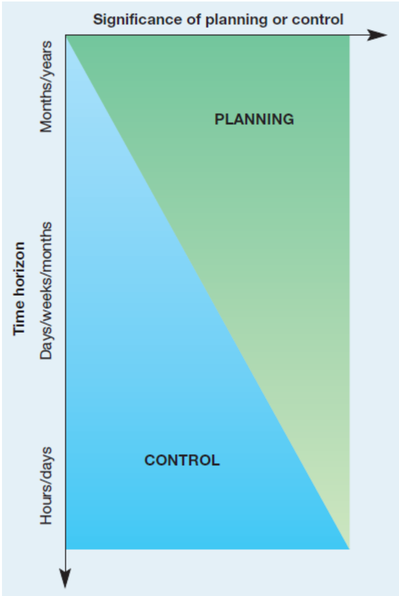

Figure 4: Difference of Planning and Control Significance (Slack et al., 2010)

How these flows are interconnected can be difficult to imagine. Therefore, it may prove useful to have a way of visualizing them. One way of visualizing the production control, is through the Production control model presented by Strandhagen & Skarlo (1995).

3.2.1 Production Control Model

The production control model was developed by Strandhagen & Skarlo (1995) and was made to enable the planning and organization of the production and logistics system a competitive advantage.

The Production Control model has been successfully implemented in several companies i Norway. According to Alfnes & Strandhagen (2000) has over 20 manufacturing companies successfully applied the Control Model Methodology . The method is based on the six steps illustrated in figure 5: *Project start, Mapping, Analysis, Design, Implementation, and Project work and training.* The first three stages is focused around getting the purpose of doing the project, and mapping the current state of the system. The three latter stages is aimed at presenting a future state (TO-BE) of the system, implementing it and making sure the company is able to continue the process on their own.

For this research, the main focus has been on steps two-four. Step one, and some work at step two has already been done as part of the ManuNet 4.0 project. However, in step two this research did complete the AS-IS production control model. In step three, areas for improvements were identified. Lastly, a proposed TO-BE solution were generated in step four.

The main elements of the production control model should describe how materials flow through the company, how the information flows, what actors are present, what ICT systems are applied, where processes and inventories are located, and what control principles are applied where. In addition, there should be mentions about market, layout, and performance.

Figure 5: The Control Model Process

4 Pipelife Norge AS

In 1952, Bjørn Large began producing plastic pipes in Norway. Later, in 1969, Martin Botten started producing plastic pipes at Surnadal and in 1973, the company Mabo Transport was created. Mabo bought Large plastic industries in 1989, and the facility in Stathelle was bought the year after. This company were to be know as Pipelife in 1999, and has been a part of the Pipelife corporation since. Their mission and vision are:

Mission: *Pipelife produce and distribute plastic pipe systems of high quality and value to Norwegian customers and selected export markets.*

Vision: *Pipelife will lead a sustainable development, i an valuable partnership with their customers, employees, owners and surroundings/environment.*

Pipelife Norge AS has become Norway's largest producer and distributor of plastic pipe systems. It is part of the Pipelife group, in which is part of the Wienerberger group. Pipelife Norge AS consist of two manufacturing facilities: Stathelle and Surnadal. The majority of Pipelife's production is exported. Pipelife Norge AS is part of Pipelife's Europe North department and has production and trading operations in Norway, Sweden, Finland and the Baltic states.

The facility in Stathelle produce polyethylene (PE) pipes of large diameter and length. In Surnadal, there are production of Polyvinyl-chloride (PVC), Polypropylene (PP) and Polyethylene (PE) pipes for water, sewage, gas, cable protection and electrical installations. There are also research and development (RD) activities performed at the Surnadal Facility.

4.1 Market Characteristics

Pipelife is present in a several markets segments such as plastic pipes and -parts for (1) drainage- and sewage systems (DSS), (2) Heating- ventilation-, and air conditioning (HVAC), and (3) electrical cables. All of these is markets where Pipelife is considered market leader (market share above 50%).

Pipelife's major competitors in Norway are Wavin and Uponor. In addition, there are several minor competitors present, as well as increased competition from European companies. In other terms, Pipelife is market leader in a market with few large actors, and many smaller. Compared to the smaller companies, Pipelife has the opportunity to take advantage of economies of scale, and production of scale.

4.2 Crafting Department

Although Pipelife produce many different standard products. The Crafting Department at Pipelife Norge is responsible for creating non-standard products in which are difficult, or unprofitable, to produce from standardized production lines. The products in the CD varies in term of quantities, entirely dependent on the customer needs. However, there are some products in which are produced as somewhat standard products such as some types of bent pipes.

4.2.1 A New Layout

Pipelife is currently looking into two options for improvements in their production facility: layout optimization and automation. The Crafting Department has previously been consisting of manual machines only. However, Pipelife is currently planning to implement automated stations to their CD to improve efficiency of the section. This is also incorporated into the new layout design illustrated in figure 6.

What can be seen in the new layout is first of all the inclusion of automated stations, the saw (left side in the illustration) and the milling machine (Top right). Both of which are planned to be fully automated stations where only feeding of the magazines is done manually. As well, the CD is split (more or less) into two parts depending on the products, creating a (more or less) cellular layout. This would imply that only similar products are made within each *cell*.

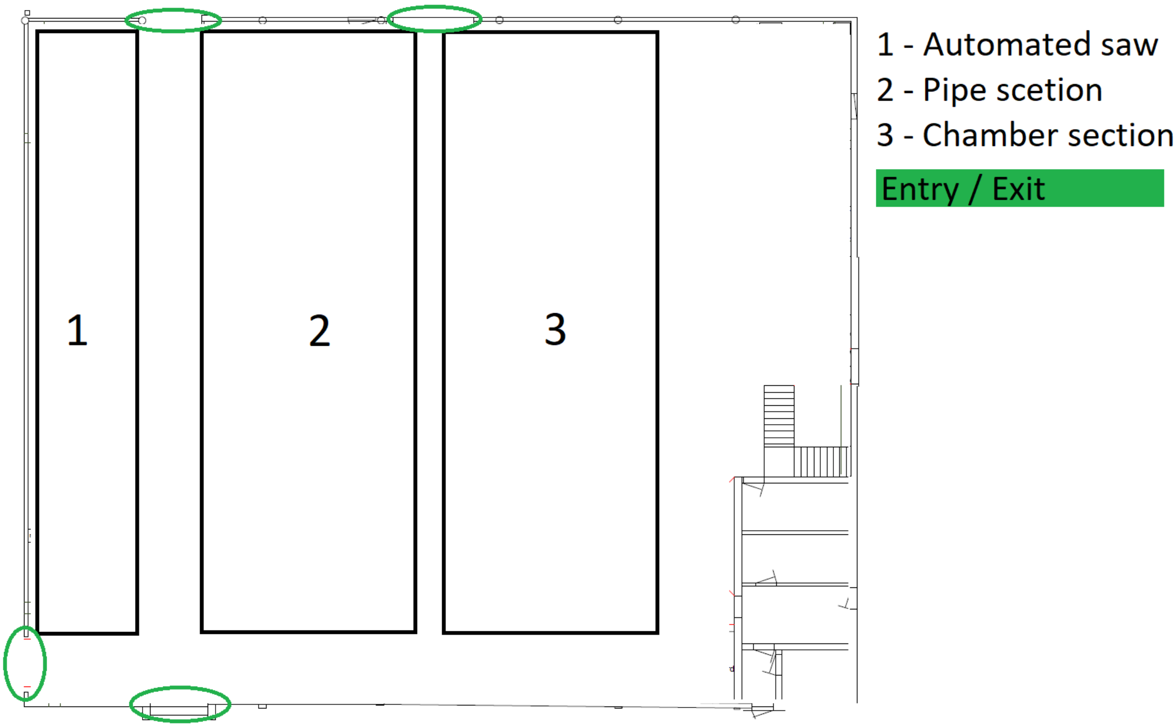

Figure 6: New Layout of the Crafting Department

4.3 Product Characteristics

The Crafting Department at Pipelife Surnadal produce two main products, although in different dimensions and forms: customized pipes and drainage/sewage chambers (hereby referred to as chamber). The customized pipes being made in the CD, are mainly pipes for drainage and sewage, bent into certain angled for fitting in the systems. Laying pipes can be challenging due to different obstacles in the ground, such as other water systems, electrical cables, bedrock or similar. Straight pipes aren't always sufficient, introducing a need for bent pipe. Examples of the produced pipes are illustrated in figure 7 and -8. Chambers are junction points in these systems, connecting pipes. The design of chambers depends entirely on each single system, introducing the need for customized chambers. Customization include drilling of entry and exit holes, and attaching pipes to these new holes. See figure 9 for illustration of one type of chamber.

Product Characteristics in the Crafting Department

Products in the CD are a mix of product categories. Most of the pipes are pre-designed

Figure 7: Example of a PVC Pipe

and standard products, and there are standard chambers that require no or little adjustments. These products are put in the make-to-stock category. There are also some products, at least of the chambers, that are customized to stock. These are customized standard chambers which are cut and have gotten installed new pipes on it, but are not necessarily finished. This is due to several reasons, one is that many of the customized products share similar designs in such a way that one can produce partly customized chambers that acts like a foundation for the finished designs. A different reason is due to long set-up times. The cutting and welding of the chambers does require a high level of accuracy, and adjusting the machine to cut in the correct angle may be time consuming. Similar is when components are welded together. This also require high accuracy, and to minimize the time spent on set-up, some chambers are then made in batches in order to save time.

Among the bent pipes, there are much that are standard products, with predetermined bending angles and lengths. The pipes are heated, before a weight are put inside the pipe for bending. Here it is the gravitation that does the work, and after some time the pipe is cooled and bent in the desired angle. This it is packed and shipped. Most of shipments are sent in batches of 12, but there are also smaller batch sizes.

On the other hand, chambers does offer a wider range of customization and may be fully

Figure 8: Example of a Pragma Pipe

customized depending on the customer needs. Although, the components used are more or less similar no matter the product. The differences lie in diameter size of the stock chamber and stock pipes in which are welded on.

Products can be categorized based on the customer order decoupling point (CODP). The CODP places products in categories depending on how far into production the customer can adjust their products. The categories in the CODP are illustrated in figure 10, where the triangles represent the CODP as well as describe the production segment (MTS = Make-to-Stock, ATO = Assemble-to-Order, MTO = Make-to-Order, ETO = Engineer-to-Order). Activities before the COPD are based on speculation and should follow a push strategy. Products before the CODP are produced based on expected demand and *pushed* into the production. After the CODP, activities are based on actual customer orders and *pulled* forward. The products made in the CD are a mix of ATO, and MTS. Not all products that are made are produced towards a specific customer order, hence MTS. These are to some extent bent pipes, and the semi-finished chambers that also act as finished products. Those products that are produced towards a specific customer order is based on pre-produced components and is therefore categorized as ATO. This include those products not in the MTS segment.

Figure 9: Example of a Chamber

4.4 Process Analysis of the Crafting Department

In this section, a description of the process in the CD will be presented. Pipe production and chamber production will be presented separately. The processes is illustrated in a production control model (see section 3.2.1 for explanation of production control model).

Pipe Bending

The raw materials to the pipe bending process originate from two sources. There are the pipes that are produced within the facility in the main production areas and there are the intermediary products that are installed on the pipes (Gaskets, plugs etc.). Intermediary products are bought completely, and the pipes are produced internally from granulate

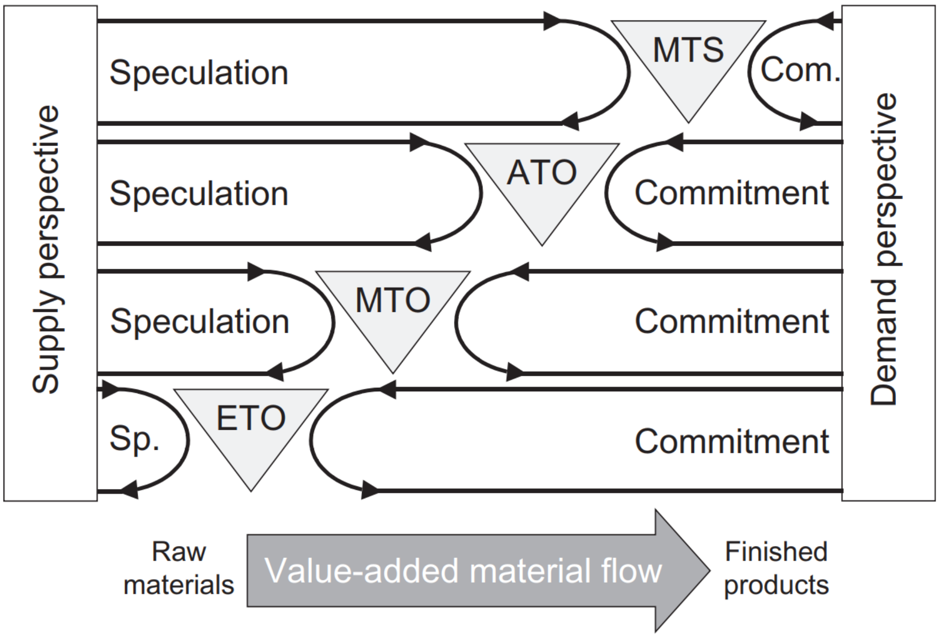

Figure 10: The Customer Order Decoupling Point (Rudberg & Wikner, 2004)

stored in silos or bags. Both raw material sources are manually counted to determine storage volume. The intermediate products are stored in a separate storage building. The customer order decoupling point for pipes are placed at the two-step storage. Up until this point, products are produced based of historical- and forecasted future demand (push). At this point and onwards, production is based on actual customer order (pull).

For the pipe production, Pipelife receive granulate in bulk, in which are then transformed into pipe bend blanks and put on storage. They are then moved into the two step storage, the first are connected to the Crafting Department. For those blanks that are cut, it has to be made a socket in that end in order for the pipe to be connected to other pipes. This is the area where the intermediate products are installed. Any unused products are transferred back to the storage building. After they have got sockets installed, they are transferred back to the two step storage. The next activity is the pending process. The pipes are heated before a weighted tube are out inside the pipe itself. Then it is put on a type of stand where the gravitation does the work of bending the pipe. They are then packed in a cardboard box and put on the two step storage. The last step is to transfer the finished products to the finished goods storage. The whole process is illustrated in figure 11, with explanations in figure 12.

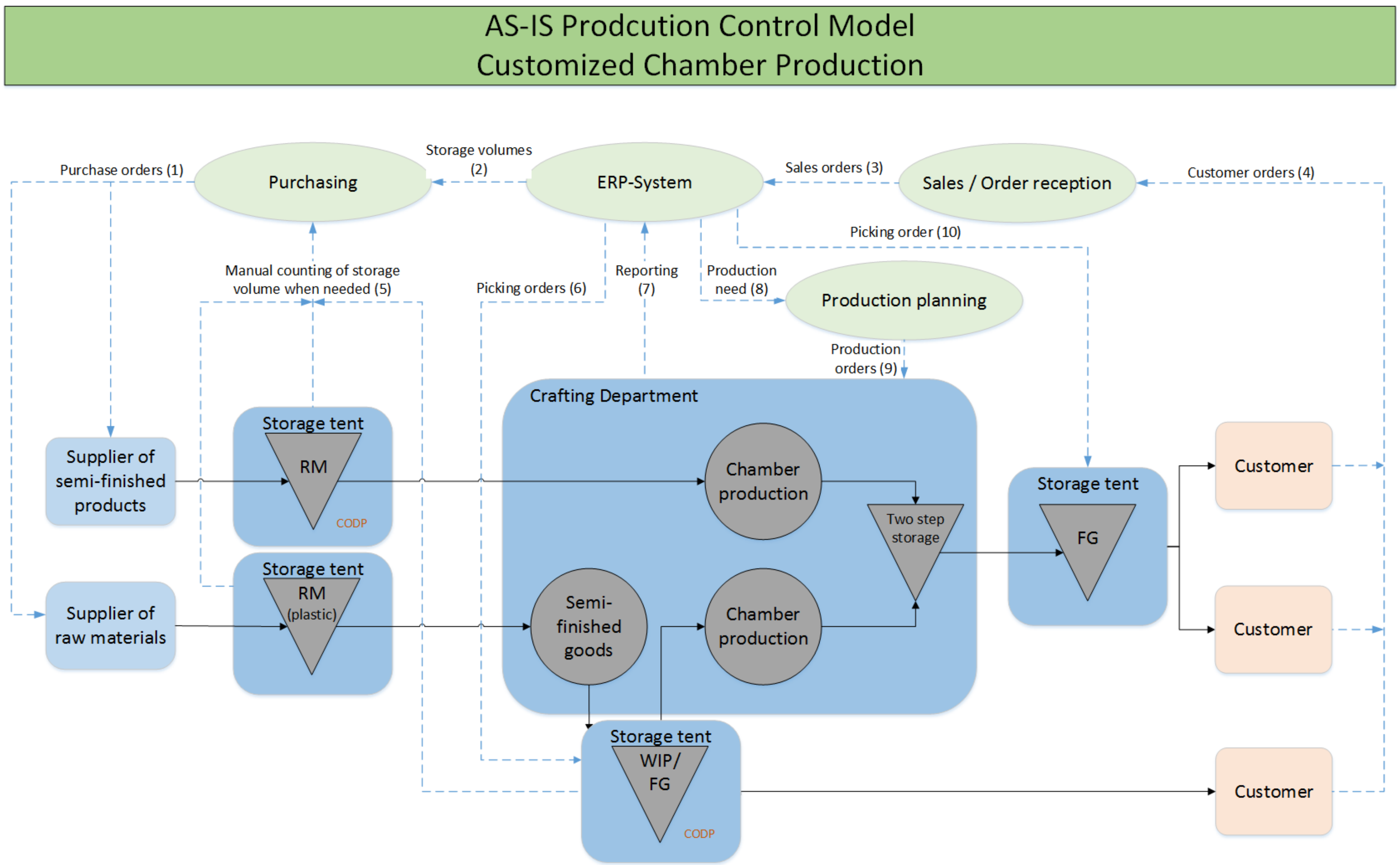

Figure 11: AS-IS Control Model of Bent Pipe Production

Flow descriptions

Flow	Explanation
1: Purchase orders	Release of purchase orders from purchaser
2: Autogenerated purchase orders	Purchase orders for approval by purchaser based on sales orders and forecasts
3: Sales orders	Aggregated sales orders based on customer orders
4: Customer orders	Actual customer orders
5: Manual counting when needed	Regularly manual counting of inventory by purchaser
6: Reporting	Reporting of actual production and deviations in production, including waste
7: Production need	Production needs based on sales, inventory level and forecast
8: Production orders	Release of production orders to production
9: Picking orders	Release of picking orders for finished goods

RM: Raw Materials
FG: Finished Goods
WIP: Work in Process
CODP: Customer Order Decouplic Point

Product flow →
Information flow ⇢

Figure 12: Flow Description of the AS-IS PCM for Pipe Production

Chamber Customization

The the customized chambers, not all blanks are produced internally. Some semi-finished products, those which have dedicated production lines, is produced internally from plastic stored in a separate storage building. The rest of semi-finished products are bought from suppliers. Storage volumes of bought semi-finished products and raw material plastic are manually counted when needed. From the raw material plastic, the internally produced semi-finished products are produced and then put in the storage location. This is where the chamber production process become complicated as some semi-finished products is also finished products. The products in which are sold as semi-finished products are the transferred out of the storage and sent to the customer. The other semi-finished products are taken back in to the Crafting Department for further customization. Here, the produced and bought semi-finished products are the customized to the customers needs and put in the two-step storage. Finished products are then transferred to the finished goods storage. Some semi-finished products are produced in batches due to the long set-up times. The whole process is illustrated in figure 13, with explanations in figure 14. The CODP for chambers is placed at the storage for purchased semi-finished products, and at the storage for produced semi-finished products. As some of the semi-finished products also act as finished products, there are a mix of make-to-stock and make-to-order segments. This makes it challenging to determine the actual COPDs and the boundaries for control principles. Since products can potentially be placed in both segments, there are risks for errors due to products being controlled by both pull and push principles. Similar as to pipe production, activities before the CODP are based historical- and forecasted demand.

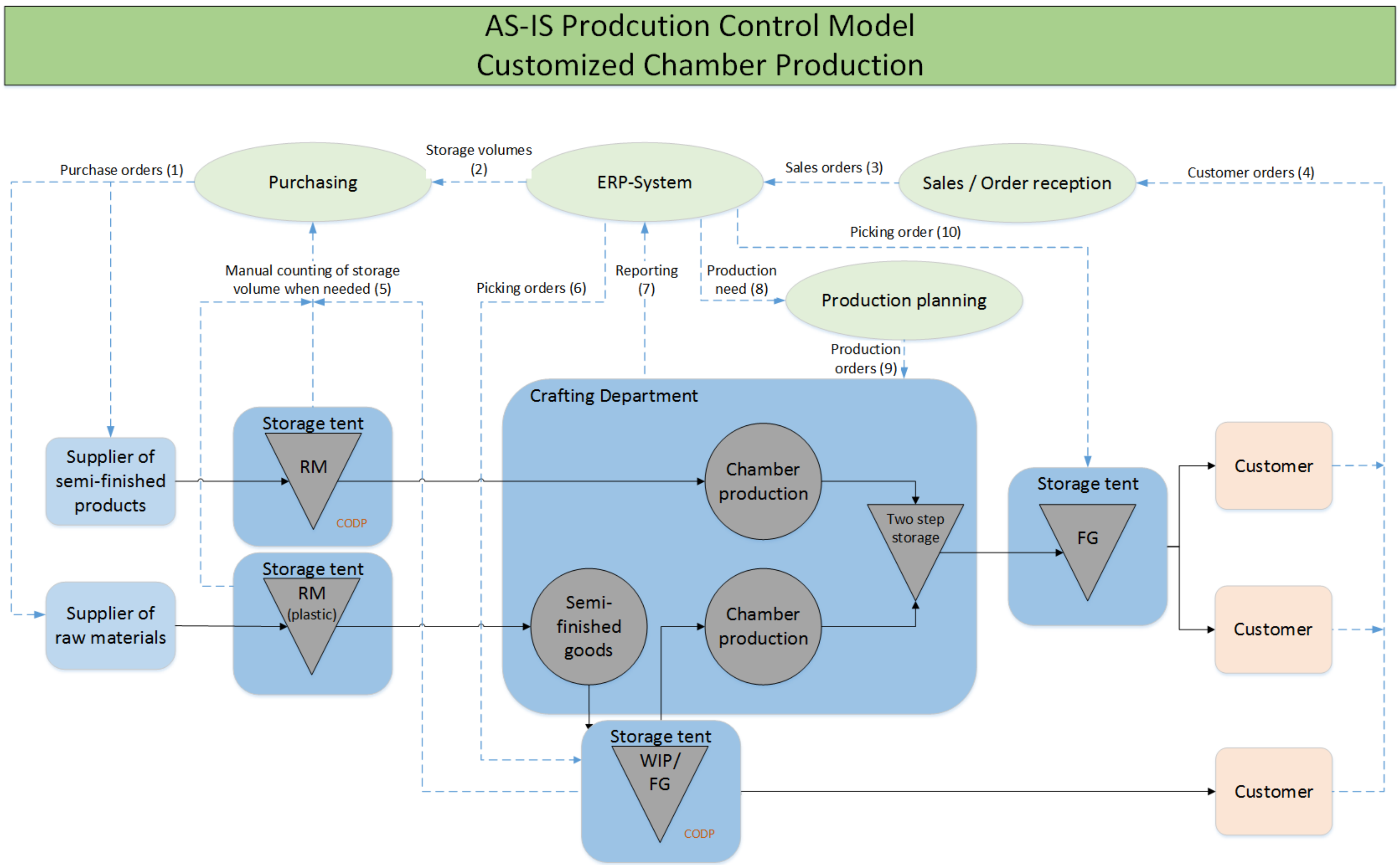

Figure 13: AS-IS Control Model of Chamber Production

Flow descriptions	
Flow	Explanation
1: Purchase orders	Release of purchase orders from purchaser, adjusted for strategic purchasing
2: Autogenerated purchase orders	Purchase orders for approval by purchaser based on sales orders and forecasts
3: Sales orders	Sales orders created from aggregating customer orders
4: Customer orders	Received customer orders
5: Manual counting when needed	Units registered by RFID readers and sent to ERP-system for automatic determination of inventory level
6: Picking orders	Released picking orders, based on customer orders, for picking of FG
7: Reporting	Reporting of actual production and deviations in production, including waste
8: Production need	Generated production needs from ERP-sytem, based on sales, inventory level and forecast
9: Production orders	Release of production orders to production
10: Picking orders	Released picking orders, based on customer orders, for picking of FG

RM:	Raw Materials
FG:	Finished Goods
WIP:	Work in Process
CODP:	Customer Order Decouplic Point

Product flow

Information flow

Figure 14: Flow Description of the AS-IS PCM for Chamber Production

4.5 The Challenges Found at Pipelife

During the preliminary evaluation of the production facility at Surnadal, there was identified three main overall challenges related to their production:

- Inventory Inaccuracy
- Tracking and Tracing of Products
- The Flow of Information and Materials is sub-optimal

Inventory is often registered in a system, for example an ERP-system. However, sometimes the inventory level registered here may differ from the actual inventory found in the facility. This is called inventory inaccuracy.

Due to items with several storage locations there has been a challenge in tracking and tracing products. Actions to be taken here is to eliminate the multiple storage locations, something in which would likely result in large infrastructural changes and costs such as investment costs, down time etc. A different action would being able to keep track of the products at all times, and to have a way of monitoring items.

The final challenge was challenge with flow of material and information. There has already been worked out a new layout for the Crafting Department at Pipelife, hence an action towards improving the material flow. Improving the flow of information would be to be able to utilize the information in which are available, and then make it available to persons capable of utilizing such information. This research will focus the most on the latter since the material flow will be different with a new layout. Thus, a new inspection should be performed after the layout implementation for identifying any reoccurring, or new, challenges to material flow, and having a foundation on which the study is based on.

With these overall challenges in mind, there has been observed some more specific challenges in relation to these during previous visits. These challenges is summarized in table 6.

Common challenges	Registration of wreckage Lacking overview of intermediate goods (Plugs, gaskets) Sub-optimal solution for withdrawal/return of intermediate goods
Challenges related to pipe production	Inaccurate counting of products due to different basket sizes Fuzzy routines for system registration No list of already cut 6m pipes
Challenges related to production of chambers	Difficult to keep overview due to several types of chambers

Table 6: Specific Challenges in the Crafting Department

During the interview with Pipelife, some of these were concluded as solved. This included lacking overview of intermediate goods, in which were solved by having a designated organizer taking care of this. However, this keep the system human dependent and vulnerable of absence of the organizer. Registration also was somewhat solved, although it still require manual registration. Return and withdrawal of intermediate goods is still a challenge and will be addressed in the proposed system.

The challenge of keeping overview of chambers will also be, to some extent, addressed in the proposed system.

5 The Proposed RFID System

This section will present the artifact resulting from the design cycle part in Design science research. With the input from the theory presented in chapter 3, and the context given in chapter 4, the outcome is a system proposal for an RFID system for Pipelife. This proposal is what will be presented in the following chapters.

5.1 Proposed System Design

Two of the strategic focus areas of Pipelife are *"Smart products"* and *"Smart Manufacturing"*. Smart products mean products in which have technology embedded in the product itself (Porter & Heppelmann, 2015). Smart manufacturing is smart products that are interconnected and connected to a common manufacturing platform. By introducing the RFID chip to the products, making them able to store and send information, allows the products to be converted to smart products. In such a way, the technology is embedded in the product. With RFID readers connected to a common system platform and also the ERP-system, this lay the foundation for a smart manufacturing strategy.

The proposed system is a mix of solving some problems for Pipelife, as identified and elaborated on in earlier sections, and creating additional value and new features for Pipelife. The proposed system should also be available for expansion, both within the factory and in term of feature, but also in term of the supply chain.

The proposed system in based upon the new layout that has been worked out and is to be adapted in Pipelife Surnadal. Whether this layout is optimal, is yet to be discovered, but it is most relevant to build the system using the newest layout and the one that will be in place. However, as showed by Chen et al. (2013), the RFID system may aid in determining the performance of the system compared to the old system. That will, though, imply that the RFID system in applied to the old layout as well to have a reference model.

In short, the system will present a feature to keep track of pallets of intermediary products, eliminating the need for manual search within the factory. As well, combined with other technologies, it should also eliminate the need for manual inspection to determine volumes. Secondly, the system will act as a performance measurement for chamber production. Being able to determine time for arrival and departure from a work station will facilitate time performance measure of work stations and employees. Third, the system will present a feature for automatic reporting from production to the ERP-system and eliminate any manual reporting. Table 7 will present the suggested reader positions in the Crafting Department.

In the next sections, there will be presented an approach for how to implement the system, and how implementations will ease the challenges seen at Pipelife and how additional values will be created.

Step 1: Creating Smart Items

In order to create an RFID enabled shop floor, the first step is converting the items into *smart items* (Qu et al., 2012). As a step in this process, one have to identify and determine which items should be *smart items*. In order to do this, the challenges of Pipelife should be examined, as well as the opportunities arising from RFID.

For Pipelife, a challenge has been inventory control and keeping reliable data on inventory levels, especially on intermediary products. One source resulting in this challenge is the use of pallets and keeping track of the inventory within the pallets. As tagging each single intermediary item is likely to be unfeasible due to the multiplication of total tagged items, different solutions should be investigated. Pipelife is already looking into sensor technologies through a cooperation with Eye-Watch on solving this issue. A different approach could be to use optical technologies to monitor the item level, or to adapt a Kanban system, both potentially in combination with RFID.

From the interview with the purchaser at Pipelife, it was mentioned that the Crafting Department covers 10-15 intermediary products, with the amount of pallets ranging from 3-10 per article. This suggest an amount of pallets from 30 to 150. These pallets should be converted to smart objects so that the need to manually locate the pallets are eliminated. This would result in the real-time information of the number of pallets in the facility, and where they are located. Combined with readers in the places where the pallets are passing through, as well as at the storage location, should enable the locating-feature of the system. This would also allow for flow analysis, and may help in detecting bottlenecks.

An important question is where to put the RFID tags. Chambers are subject to drilling and fitting of new pipes, meaning a badly placed RFID tag may run the risk of being drilled to pieces. However, chambers are rarely drilled in the top part, meaning a tag placement in the top of the basin should be relatively safe from getting ruined. Figure 15 illustrates a possible placement for RFID tags on customized basins.

Figure 15: Example of Tag Placement on Chambers

Time studies on chamber production was also lacking according to Pipelife. A method to achieve this could be to attach RFID tags to the chambers, where product ID and customer order (if existing) is stored. The chambers are not produced in such large volumes as pipes, making the tagging of each chamber more feasible in terms of cost of tags. According to Ray (2018), does active tags cost between 40 NOK and 120 NOK ($5-$10) a piece, and passive tags at 0.40 NOK to 1.20 NOK ($0,05-$0,15). Therefore, with a low to medium volume of tagged products, a feasible solution should be achievable. This is, however, subject to discussion as the value and potential cost savings need to be compared to the total unit costs. Such an analysis should be done for every system. During the company visit at Pipelife, the practical applicability of attaching tags to chambers were investigated, and due to its groove surface there should be possible to attach RFID tags to the outside of the chamber without the risk of tag damage during drilling and welding. Although, there it would be more exposed for external damage during, for example, installation.

As a very rough estimate on the costs of tags, a unit Price of 1,2 NOK is used. With 150 pallets for intermediary products, this result in an investment cost for tags of about 180 NOK. With all pallets in the CD accounted for, which are 7000 a year according to Pipelife (ref: Appendix A), that would imply cost of tags being 8400 NOK. However, that being in a whole year, there should be possibilities to reuse the tags. RFID tags allows for rewriting of the memory, meaning tags can be reused and a possible reduction of tag investment cost. However, using active tags could according to Ray (2018) reduce the total cost of the system due to readers not having to be as powerful. Therefore, a cost estimate using both active and passive RFID tags should be presented before the final decision is made.

Step 2: Installing Readers

The second step, according to Qu et al. (2012), is equipping auto-ID readers. There will have to be decided how many readers and where they are to be placed. A greater number of readers will positively benefit the system in that more information will be available. However, it relies on the readers being put on places where its information add value. On the other hand, more readers does also imply a higher investment cost, and likely cost related to maintenance. A total of nine readers are applied in the proposed RFID system. Five of which are low range readers, and four longer range. As stated by Ray (2018), a passive reader with antenna and needed equipment may cost up to 28500 NOK (3000 euros). Therefore, minimizing the amount of readers can significantly reduce investment cost. Also, with as many readers as nine being necessary, it may be worth looking into active RFID tags for the cheaper readers.

To facilitate the location of pallets with intermediary products, readers should be placed in all area transits in the facility, such as the entry point to the facility, the entry points to all areas within the facility (such as the Crafting Department and the two-step storage), and the exit point on which the products are transported to the final goods storage (alternatively at the entry point of the final goods storage). This would allow for rough location. More readers could be installed to fine tune the locating function making it more precise. These readers need to have a range covering the whole passage, so that tags passing through will be read. This could imply a range up to approximately 5m, and maybe even more.

For time studies on chamber production, readers need to be placed at each work station related to chamber production. These do not require similar range as in the entry points. Optimally, there should be one for registering arrivals and one for departure of products. A different way is to measure how long a tag is within reading range. This would also reduce (to half) the number of readers in which need to be placed. With these readers in place, the system should be able to automatically report to the ERP-system the progress of any tagged products. This progress reporting could also be sent to the customers if required, for example through e-mail updates, an online web-based order status application, or through an mobile application. It should also be able to generate performance reports that distinguish between products, dimensions, and employees. For any waste there should be a separate location (such as a bin) in which has an installed reader. Whenever a product is within range of the reader, it would be registered as waste. Pipelife uses status codes for the products, and a unique waste status can be created. This should then register the product as waste, remove the products and components from inventory, and create waste report. The only manual work will be to describe the cause of the waste.

A suggestion to where RFID readers should be placed is described in table 7 (See figure 6 for layout). This show the most important areas, and maybe more interesting, the amount of readers in which is necessary. The waste collection should be a separate area.

#	Location
1	Passage to two-step storage
2	Passages to the rest of the factory
3	Passage to final goods storage
4	At each work station for chambers customization
5	At the waste collection

Table 7: Placement of Readers in the Crafting Department

Step 3: Create Software System
When the items are tagged, and readers are placed, the back-end systems will have to be created. This will include receiving the data from readers, process the data to get the desired outcomes, store this data in a database, and alternatively sending the data to an integrated system (or a system that communicates with the RFID system, such as a web page or an ERP system).

What is important for the software is that it is created in a language in which can communicate to several software's. To broaden the applicability of the system and the software, it should also use open source language to avoid the licensing costs and limitations that comes with closed-source languages. In a perfect world, all similar systems would be created in the same language, hence they should all be able to be interconnected without any middle-ware software.

5.2 The Next Steps for Pipelife

This study has only presented a proposal for a system in which Pipelife can adapt. Although, there are yet some tasks to be done. These tasks are presented in this section.

First, in order to justify any implementation of the proposed system, the business case need to be made. The costs related to implementing the system need to be identified, determined, and calculated. Costs include hardware-, software-, and consultant cost, but also cost such as those related to maintenance and repair, and unproductive time during implementation. As well, a more thorough estimation of cost reduction should be carried out to establish for example payback time of the investment. Second, the technical issues need to be considered and measured need to be taken in advance of the implementation.

Third, the software need to be created with the desired functionality. Considerations presented in step 3 for the implementation plan should be followed. Lastly, to get a wider picture, benefits that affect more actors in the supply chain should be investigated. This would perhaps allow for further enhanced benefits of such an RFID system, and even sharing of costs and related risks. This would also benefit the business case, mentioned above.

5.3 New Production Control Model

The production control model does not change drastically, but there are still some changes to the model that comes from the proposed system. The changes are pretty similar for both segments (pipes and chambers), therefore the changes will be elaborated upon jointly in this section. The TO-BE control models are presented in figure 16 and 18, with flow explanations in figures 17 and - 19, respectively.

The changes doesn't affect material flow directly as much as it affect information flow. Information flow in the proposed system, more specific the information flows from raw material storages, should flow automatically from where it is captured an to the ERP-system. This enable faster capture of this information, as well as real-time estimation of production- and purchasing needs. With an performance analysis system, deviations from standard operation times can be identified to capture, for example, failures in machines or sub-optimal processes. Additionally, with the capture of process information, information about products, completion, and logistics can be sent to customers to support planning and coordination further downstream in the value chain.

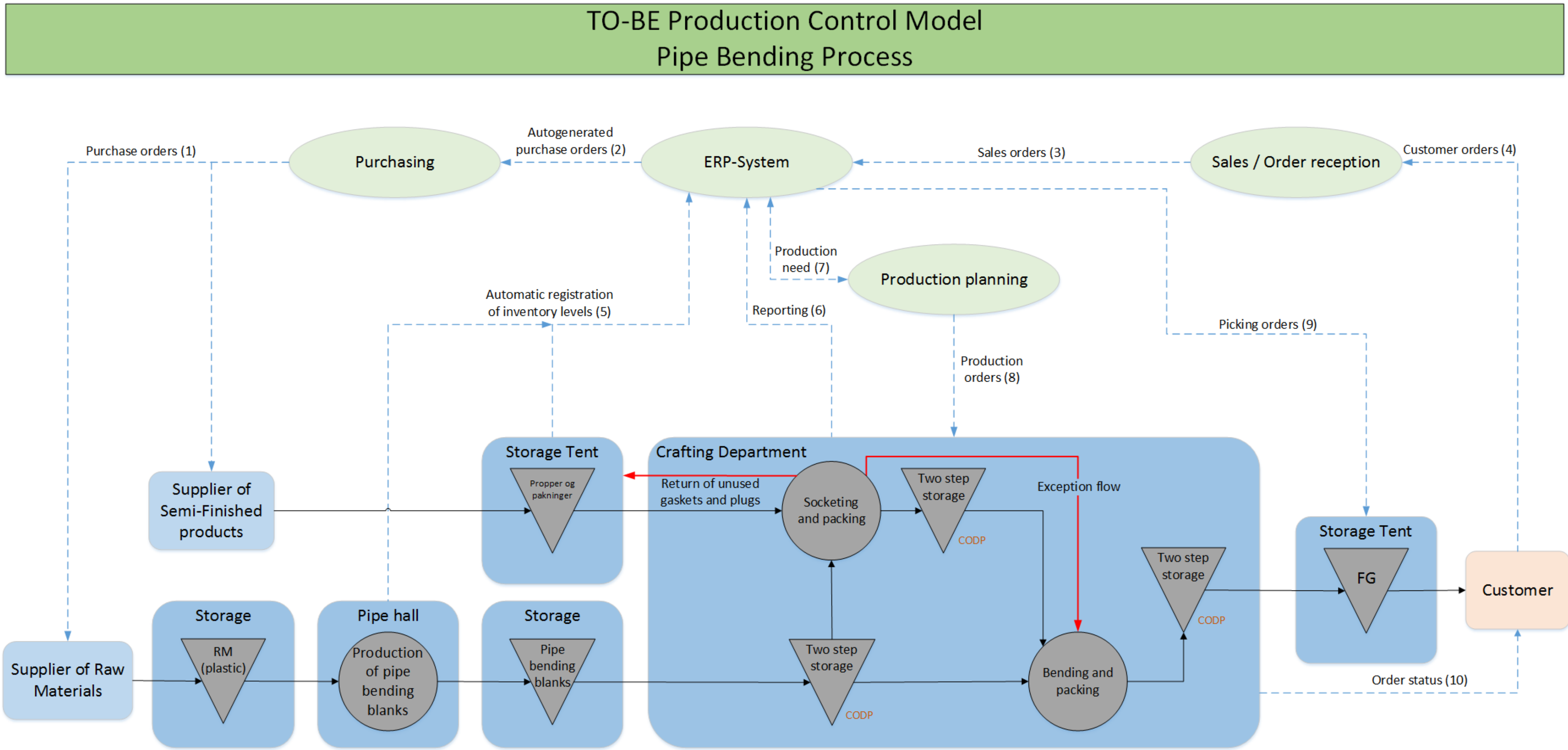

Figure 16: TO-BE Production Control Model - Pipe

Flow descriptions

Flow	Explanation
1: Purchase orders	Release of purchase orders from purchaser
2: Autogenerated purchase orders	Purchase orders for approval by purchaser based on sales orders and forecasts
3: Sales orders	Aggregated sales orders based on customer orders
4: Customer orders	Actual customer orders
5: Automatic registration of inventory levels	Units registered by RFID readers and sent to ERP-system for automatic determination of inventory level
6: Reporting	Reporting of actual production and deviations in production, including waste
7: Production need	Production needs based on sales, inventory level and forecast
8: Production orders	Release of production orders to production
9: Picking orders	Release of picking orders for finished goods
10: Order status	Update on order status is sent to the customer

RM: Raw Materials
FG: Finished Goods
WIP: Work in Process
CODP: Customer Order Decouplic Point

Product flow →

Information flow - - →

Figure 17: Flow Description of the TO-BE PCM for Pipe Production

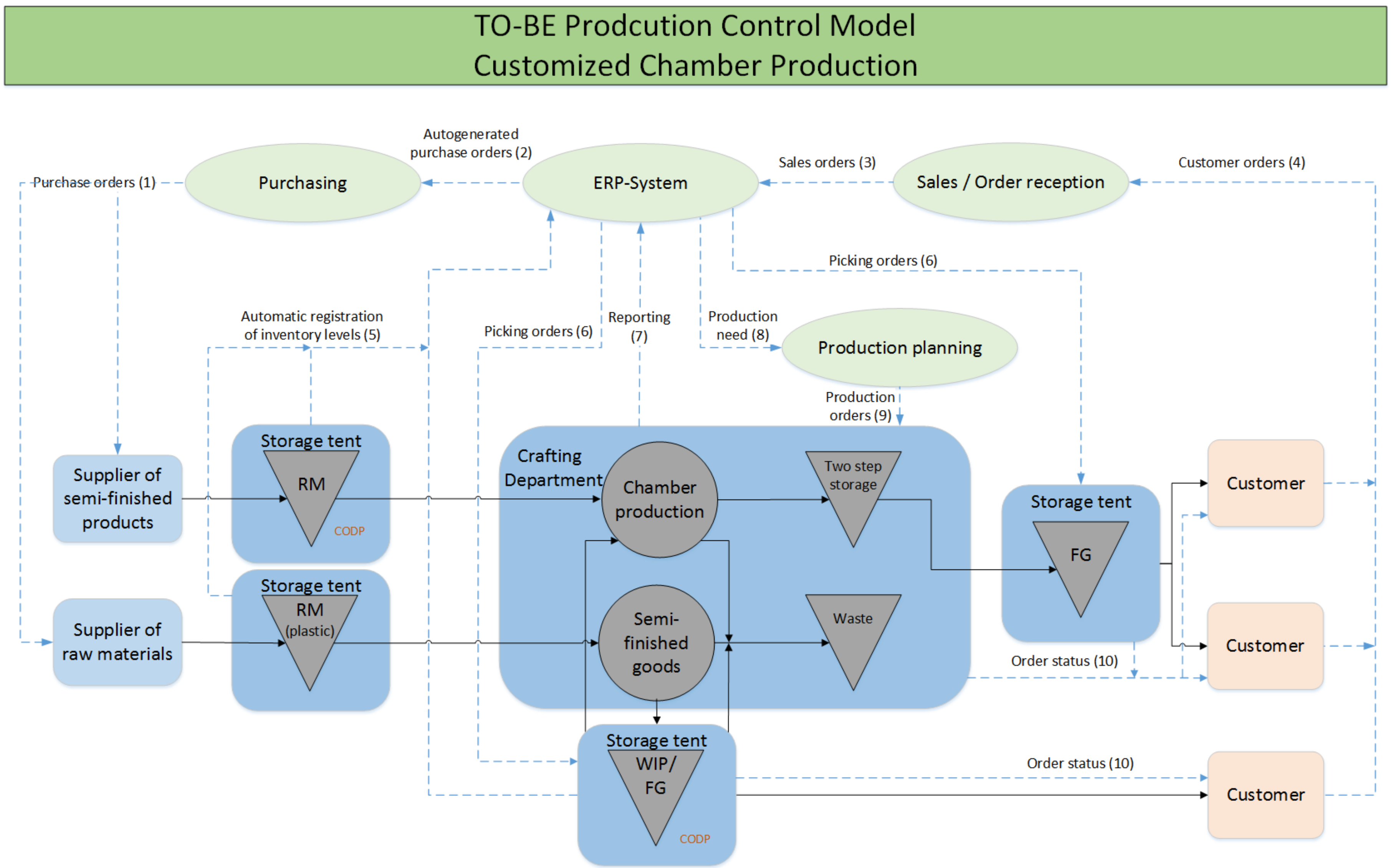

Figure 18: TO-BE Production Control Model - Chamber

Flow descriptions

Flow	Explanation
1: Purchase orders	Release of purchase orders from purchaser, adjusted for strategic purchasing
2: Autogenerated purchase orders	Purchase orders for approval by purchaser based on sales orders and forecasts
3: Sales orders	Sales orders created from aggregating customer orders
4: Customer orders	Received customer orders
5: Automatic registration of inventory	Units registered by RFID readers and sent to ERP-system for automatic determination of inventory level
6: Picking orders	Released picking orders, based on customer orders, for picking of FG
7: Reporting	Reporting of actual production and deviations in production, including waste
8: Production need	Generated production needs from ERP-sytem, based on sales, inventory level and forecast
9: Production orders	Release of production orders to production
10: Order status	Update on order status is sent to the customer

RM: Raw Materials
FG: Finished Goods
WIP: Work in Process
CODP: Customer Order Decouplic Point

——— Product flow ———→
– – – Information flow – – –→

Figure 19: Flow Description of the TO-BE PCM for Chamber Production

5.4 Assumptions and Implications

With the new system design, there are some factors that need to be considered. One of which are the foundation on which the design is built. One element of this foundation is the facility layout. The layout has been subject of change and a new design will be implemented in the near future. The proposed system in this research is based on the new facility layout. Whether this is the optimal layout is not certain and should be considered as an unknown variable for the performance. A way to verify this layout change would be to create a similar RFID system (as the proposed one) to the old layout before the change, to have a reference point on which the performance can be assessed.

6 Discussion

This section will cover the discussion part of the research. The main topics of the discussion will be the research questions and how the study has answered these. In addition, there are some other considerations in which are elaborated upon in this chapter.

6.1 Research Aim and Research Questions

In section 1.3, a stated research aim was presented with supplementary research questions. This section will evaluate whether research questions has been answered.

1. What are the main benefits and challenges to RFID technology?
Through the literature study, several benefits and challenges was identified. The main benefits of- and challenges to RFID technology are presented in section 3.1.2.

2. How can RFID technology support real-time decision making?
The very nature of RFID is the ability to automatically capture information from tagged products or goods. With readers (fixed position or mobile) connected to ERP-systems through for example WiFi, information should be available practically at the same time it is captured. That is the first requirement for any real-time decision making systems, hence RFID can be seen as a major enabler for real-time decision making. Compared to different Auto-ID technologies, such as barcode and QR, RFIDs ability to simultaneously read multiple tags with no manual influence is what make RFID a preferred choice of technology.

To adjust for technical issues, changes in customer demand, or scheduling changes, the decision maker should know the status of the production system at the current time. If this status is delayed, the decision maker run the risk of basing decisions on the apprehension of the status, and not the actual status of the production system. For example, the decision maker may release production orders to production, believing that raw materials are is place and sufficient, and that production have got the needed capacity. If then the delivery of raw materials are delayed, or one of the work stations is jammed, this could result is longer lead times than expected and reduced customer service level.

What has been showed by several researchers is that RFID is a key enabler for many types of systems. RFID offers the feature of automatic data capture and information in real-time. Many intelligent systems in which are created to support dynamic operations, rely on such information in order to operate desirably. With the approach of industry 4.0, where production is set to be controlled in the cloud and produced off location, real-time data capture can prove crucial. The distance between decision maker and production is increased, introducing the need for a faster capturing and transmission of data. If this is not the case, similar examples as presented in the previous paragraph can be seen.

The next key factor in real-time decision making must be to getting information of value. Just *any* information would not necessarily support RTDM. In some cases, it may even counteract its benefits in that too much information is collected and the decision maker end up with much non-valuable and redundant information. It may be that the information even has to be analyzed or processed before any information of value is achieved. This puts pressure on creating the middle-ware system in a way that is optimal for decision making. A system similar to the one created by Zhong et al. (2014) could be made in order to interpret and analyze the data. Using a model to remove unwanted data and to extract valuable information from the wast amounts of data generated. A different approach is to limit the unwanted data volumes. Such an approach can follow suggestions from Guo et al. (2015) to only equip readers at those workstations in which processes key- or bottleneck operations.

3. How can RFID technology impact the production control model?
As illustrated in figure 16 and 18, there are some changes to the control model in which consider RFID. The flow of products and processes isn't changed very much, however, the major changes lies in the information flows. First of all, by having an automatic registration of products, this information can be input directly to the ERP system. This could result in purchase orders and production orders being automatically generated based on inventory level status and customer orders. This would also result in the elimination of the need for manually checking the inventory status of intermediary products, including the risk of human error and dependency of certain employees. In other terms, RFID can

streamline the information flow in the production control model to a point where *all* information is captured and sent to the ERP system. Hence, all calculations and estimations can be performed automatically in the ERP system, and distributed to the responsible department. This would result in the main task for decision makers and planners would be to control the estimations and to adjust for such things as strategic purchase and -production, special customer orders (for example orders of high priority with very short delivery time). This show how RFID can support a higher utilization of the ERP-system.

With information about processes and completion of products, this information could be sent to customers to support planning and coordination downstream in the value chain, creating a more transparent value chain. This could potentially increase the value of an RFID system, since benefits can be achieved both internally and externally. This could lead to more actors being willing to invest in a technology that can benefit the whole supply chain, reducing investment cost compared to a single-company investment. As well, information generated at one stage in the value chain may be utilized to gain value elsewhere. For example, as discussed in the interview with Pipelife, one can see options where RFID tags equipped with sensors are put in the chambers for measure of flow and water level. This would mean utilization of the RFID tag in a higher degree that just for identification and location purposes.

4. How can an RFID system be designed to fit Pipelife?

Chapter 5 present a proposed RFID system deigned to fit Pipelife, more specific the Crafting Department. For Pipelife, there was a set of challenges intended to be dealt with by the RFID system. The proposed design show how challenges related to locating/monitoring of certain products (in this case pallets of intermediary products), can be dealt with purely by RFID technology. However, combined with more advanced RTLS, a more detailed monitoring could be achieved compared the the detail level of the proposed system where the products are located mainly based on the department it is present.

Additionally, it was shown how the RFID system can support production control at Pipelife by providing both a method for performance measurement and for registration of waste. This can be a step towards optimized production. By having automatic registration of waste and standard operation times, manual work related to this registration can be eliminated and time can be spend elsewhere, preferably in value-adding activities. By eliminating non-value adding activities, such as manual registration and searching for products, a larger proportion of the total time will be spent in value-adding activities.

In several of the articles where an RFID system is implemented, the RFID implementation has been tailored to the company to fully cover the needs for the specific company. This could point towards no existing one-size-fits-all solution. Rarely two companies share the exact same production layout, meaning the RFID system will be different each time.

6.2 Other Considerations

The selected research questions do not cover the whole picture of considerations in which should be discussed in relation to RFID technology. The following sections will discuss some of these subjects.

Value of the Proposed System

The value of the proposed system is based on two aspects, what costs as reduced and what potential new feature can Pipelife benefit from. However, in the proposed system the value of the product, hence value for the customer, is not increased significantly as the the major focus has been on process improvements. This research is about RFID technology and how Pipelife as a company can utilize its benefits, not necessarily how RFID technology can increase value of the product itself. The product value increase will, however, be discussed briefly.

The current system has mainly two functions: tracking assets (pallets of intermediary products, chambers), and monitoring production times for chamber production. Then there are the functions in which could be integrated to the system for additional value and options, for example scheduling optimization programs. This can be done by incorporating scheduling optimization into the software such as seen in Zhang et al. (2014); Zhong et al. (2014). However, the value of this may be highest when product varieties are large, and for products that share similar production resources. For Pipelife, their standard products has dedicated production lines and planning should be more straightforward (compared to high variety, low volume production that is). Thus, the value of such a system may be uncertain. On the other hand, being able to have a scheduling system that incorporates set-up times could result in a better production schedule of operations in which are heavily influenced by long set-up times, such as chamber production at Pipelife.

The reduced costs come in the form of reduced labor due to elimination, or reduction, of manual work. This is mainly connected to registering tasks, and monitoring tasks. In the proposed system, the purchaser frees up around 45 minutes every week on average, and gets a more accurate and real-time status of the intermediary products. For 45 weeks of work, that is just over 10 000 NOK worth of time that can be spent elsewhere (with an hourly rate of 300 NOK). If the purchaser should be absent and the company having to use a substitute, he (or she) may spend more time and this sum would be higher. As well, most of the time that are currently spent on reporting from the production department to the ERP-system can be spent elsewhere. Yet, this is an amount of time in which need to be measured in order to establish the actual cost reduction. Both of these examples show illustrate the actual savings in such a system.

A different approach is to incorporate more of the supply chain in the system, such as suppliers, distributors and customers. Using the collected RFID data to optimize logistics flow and operations through the whole supply chain, while at the same time sharing the costs and risks associated to implementing an RFID system.

The system also include some new features in which Pipelife can benefit from. First, the ability to get automatic performance measures of work stations and production workers would help identifying less efficient areas and enable work station- and employee-specific improvements (reorganizing of work station, training etc.). Second, the value of information distributed to the customers may be emphasized. This feature could possibly ease planning and coordination upwards the value chain.

Additionally, RFID technology could present values for the whole supply chain in terms of inter-coordination between actors. These should be addressed further in later studies. Examples of this can be use of integrated sensors on RFID tags, such as elaborated upon in earlier sections. RFID technology used for business purposes across the value chain is a fairly new subject and should be investigated to determine more intra-firm benefits. An interesting observation is that in Chen et al. (2013), where lean and RFID was applied. It was observed that lean improved the whole system the most, but when it came to the value adding activities it was RFID in which gave the most improvement. This could be an indication that RFID can further enhance value adding operations, and would be applicable for companies with close to optimal processes in non-value adding activities. However, it may be that only those exact lean tools applied in that study is designed to remove non-value adding time and the results is therefore likely.

A generic system design

As stated early in this research, the aim of the design science approach is the generic design. Although it was said that generalizing design is difficult when human impact is great, the proposed system has removed some of the human interaction in the system. This can ease drawing generalized conclusions from design and testing. Due to little testing and need for more feedback to the system proposal, there is difficult to make a generalized design. However, in the following paragraph generic outcomes are discussed.

First of all, with an automatic registration of materials, thus inventory levels, this information is possible to feed directly into the ERP system of a company. This could result in a more automatic production planning and purchasing process, and would also relieve the responsible purchaser of *unnecessary* tasks such as manual control of inventory. Ultimately, this could allow for a more automated production planning and control, where such activities are done by the ERP system. Hence, the main task for the responsible employees would be to monitor the system and interact when deviations happen. This would mean a shift towards a grater focus on production control (rather than planning). However, the strategic element of planning should still be considered and therefore the production planner will still be needed.

Alternatives to RFID - Is RFID simply the best?

As stated in chapter 3, the main alternatives to RFID are barcode, QR, and biometric systems. As Shamsuzzoha et al. (2013) say, each technology has its own advantages and disadvantages and all technologies should be considered before any implementation is started.

In the proposed system, the unique features of RFID in automatic identification of tagged units are utilized. Achieving the same level of autonomous information capture will be difficult with the other technologies. However, these features comes at the cost of being a more expensive technology in terms of investments. Therefore, a proper business case should be made of RFID (as proposed earlier), and cheaper options with less features may prove to be the optimal fit for Pipelife.

Expansion to more departments

The integration of the system to the other departments should be highly feasible as the production is more predictable, both products and flows. However, as many of the products in the main facility is produced in large volumes it would not be feasible to tag each product. This would be an important issue to address if the system is expanded beyond the Crafting Department.

7 Conclusion

This study has investigated RFID-technology, and illustrated how a Norwegian pipe manufacturer can benefit from using RFID technology. RFID technology's major benefits and implications has been elaborated upon, and the historical applications of RFID has been shown through previous research. The RFID benefits are given context through the design of an RFID system adapted to the Norwegian pipe manufacturing company.

This research has, based on previous findings and experimental thinking, been able to propose a system in which should ease some of the challenges Pipelife Surnadal are faced with. This present a practical use of the benefits in which RFID bring.

The major benefits associated with RFID technology are: autonomous registration and identification in real-time, simultaneously registering of multiple units, no need for line-of-sight. Its main challenges include the three high problems (high cost, high risk, high technological threshold), as well as several technical challenges such as interference and challenge related to software integration due to many programming languages being used for RFID systems. There are also a challenge related to data redundancy.

With the mentioned benefits, RFID technology can act as an enabling system for facility process management. RFID can support decision making through its real-time data capture capability. By providing the decision maker with the current status of the system, and not a perceived status, the decision maker can base their decisions on more accurate information. RFID can also automate tasks, such as registration, to reduce the amount of manual labor. Hence, RFID can be a shift in focus for production planners from planning towards production control, where the main focus is to adapt to deviations. However, strategic planning will still be an important part for the production planner.

For the production control model, RFID enables streamlining of information flows from production to the ERP system. This could lead to a higher utilization of the ERP-system. In addition, it show that the use of RFID technology can enable more information sharing downstream the value chain. This can support planning and coordination activities across the value chain. Results from the literature study also suggest RFID has the highest contribution in value-adding activities and can be a catalyst it such activities.

Further research on this topic should consider more aspects of the system implementation, such as benefit-cost analysis to determine economic feasibility and return time of the investment (similar as can be seen in Tabanli & Ertay (2013)), and development of the software system that goes with the hardware system. It should also investigated how the system can be integrated to ERP-systems, for example SAP.

Although the system is proposed to solve some of the challenges for Pipelife, this need also to be validated in the form of field testing. This would present the actual effects of implementing such a system. Such a study would be a valuable continuation of this research.

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Appendix A: Interviews with Pipelife

During the company visit Friday 4th of May, there was arranged a tour in the production facility at Pipelife Surnadal, as well as some interviews. The interviews was partly divided into two parts, the first part, where the supply chain manager and the logistics controller was present, was carried out using some predetermined questions. The second part included on of the purchasers and was more or less a description of the process and what types of challenges is present in his position.

Interview 1

Interviewer: Sondre Sivesind Melbye

Interviewee 1: Supply Chain Manager

Interviewee 2: Logistics Controller

Interview setting: Interview was conducted during a company visit at Pipelife Surnadal Thursday 3rd of May.

Start of interview:

Interviewer: What is the current challenges at Pipelife Surnadal and how can an automated tracking- or RFID-solution contribute to solving these?

Interviewee 2: The challenge is that we are not ready for the future. None of our customers demand that we use RFID. The day the customer require RFID and it becomes a sales promoting element we need to be able to implement it fast, maybe even before our competitors.

Interviewer: In other words, it is more planning for the future than a current initiative?

Interviewee 2: Yes. We have talked about RFID since 2010-2011. We did not go through with it as there were no suppliers prepared for our needs. Especially for RFID on packs of pipes that are outside and exposed to snow and wind, and with readers on trucks. They tried it in Finland, and had no success the first years due to climatic conditions resulting in bad reading of the tags.

Interviewer: Stated challenges include technological risk, investment costs, and the need of specialist competency. What would you consider as challenges in an implementation of RFID?
Interviewee 2: Subjectively thinking, the unit cost and investment cost. But again, its important to be prepared for it. I believe this is constantly developing.

Interviewer: As in prepared for when the cost-benefit is positive?
Interviewee 2: Yes. But the cost of not having RFID is yet uncertain. Therefor the calculation of cost-benefit is very difficult to do. Today we do many unnecessary operations in which may be more efficient with RFID, but there are no current performance indicators in this area. These calculations is therefore based on estimations, in which may be very wrong when units are multiplied.

Interviewer: RFID is not only about how much cost it reduce, but maybe more about the added value. How much do you think your customers would appreciate receiving information such as real-time data on progress.
Interviewee 2: Today, the customer is not yet at a place where these things will be valued. But, we do not know if the customer will get there in the future.

Interviewee 1: The customers are not yet there. But they will get there in the future. The question is then when, and do we wait for them to request it or do we act proactively.

Interviewer: As for today, the value of the customer is not relevant?
Interviewee 2: That's a unknown variable at this stage.

Interviewer: How much, and which activities are performed today, in which are non-value adding, such as registering, transport etc.
Interviewee 2: In the production facility we have approximately 15 000 pallets of electrical tubes, and 7000 pallets in the CD. These could all be transported and registered in a different way. This could result in major cost reductions.

Interviewee 1: In relation to the crafting department, we currently have a planner in which are responsible to fill in needed intermediary products and remove those who are not needed. This is so that the production workers can focus on producing.

Interviewee 2: He also does other things such as planning and restructuring. But I would estimate an approx 0.65-0.70 FT are spent on transportation of goods in CD. Including finished goods the number is above 1.

Interviewer: Speaking of transportation. Regarding the registration. are there any registration of the products during the process, or is it only when the products are finished?
Interviewee 2: Only when it is finished. The longest lead time we operate with is approximately 3 shifts (= 24hr). Only in a few particular cases do we have products in the production for longer than 24 hours.

Interviewer: Unit-vise, is it correct that basins take the longest time?
Interviewee 2: Yes.

Interviewer: How would real-time information, for example on where the product are in the process, improve the internal planning.

Interviewee 2: I could be very useful to use RFID to measure the time spent making one basins. This could be used for analytically purposes and receiving the actual time spent.

Interviewer: Meaning benchmarking of shifts?
Interviewee 2: Benchmarking of personnel, yes. Perhaps not on the basins that take 24hr of production, but of the more common ones that takes 5-6hr. However, there would be a challenge related to supervision of the employees. That is not very popular and has to be ”sold in”.

Interviewer: Speaking of benchmarking. What type of KPI's do have in the CD?
Interviewee 2: The standard KPI we use are kg per man-hour. We then have a structure generating an expected time frame for products, in which we can benchmark versus the actual time spent.

Interviewer: Do you have any measures of the whole process, including transportation and waiting time? For example waiting between processes.
Interviewee 2: No. But the time spent on transportation in a batch of pipes are very little. These are also no standard waiting times for products between processes. This depend on the batch size. Sometimes we make several semi-finished products and put them in the intermediate storage until they are needed. Set-up of machines takes a lot of time, therefore we produce several semi-finished products.

Interviewer: One identified challenge was unclear storage locations, can you elaborate on this?
Interviewee 2: Earlier we had several organizers that had their own system, but now we have only one and the problem is therefor not as big anymore.

Interviewee 1: Something that may complicate it a bit is that some intermediate goods are also finished goods. In relation to inventory accuracy this can be a challenge. These products are registered as finished goods, but may be included as a intermediate goods in a product in the crafting department. These will only be registered as not available when the final product in CD are finished. The reason for this is mainly out of simplicity for the system.

Interviewee 2: I have an idea. How would it be if the intermediate goods are tagged as it is taken to the CD? Using RFID to tag the product towards a specific customer order may be useful. Then It would net be possible to put an order on the product as it would show as taken. This is also mainly products in which are sold as units and not in batches, it could therefor be feasible to mark each and one of them since the volume would be low.

Interviewee 2: Today, the crafting department can go get the part even if the item is allocated. Using RFID to change status to lock the product towards a customer order. If the product then require to be registered out, it would not be possible of the code has changed to status "allocated".

Interviewer: Many of the challenges was related to registering of goods, for example wreckage.

Interviewee 2: These problems are actually solved. Through two-stage storage on semi-finished goods. The system has standard multiples, and now we are registering single units to the multiples. These are, however, registered in meters and not units.

Interviewee 1: How do we solve this today?

Interviewee 2: Errors will be found during two-step storage. The planner will discover these at this stage, but this is then very person dependent and possibly source for errors. Although, it is possible to teach other people this procedure.

Interviewee 2: We have also introduced change of location, where wreckage is registered to a certain wreckage location. These are put into a basket of wreckage before the planner is counting these and registering then into the system as wreckage.These are not available for allocation. This has improved the system a lot compared to earlier.

Interviewer: Having something like live-value stream mapping, or using tracking to improve flow of goods. How do you asses the value of something like this?

Interviewee 1: I think that is of little value to us. Compared to companies like Ekornes, in which have many operations and processes and tracking the products through the operation may be of high value, we have few stages before the product are finished and the product is located in the same area the whole time. Therefore, the value of such information is little.

Interviewee 2: I agree on the total picture. But during the tour we discussed this a bit, in that one could uses such information to measure time spent on drilling, welding and such.

Interviewee 1: Yes, for measuring of time there are value for us as well. But in terms of visualization, the most important information would be to know whether it is inside the crafting department. But using it for benchmarking and logging of time it could be used.

As a tool for internal improvement.

Interviewer: With regards of value after the product has left the factory. What type of information or value do you thing RFID may have? Optionally, before you even get the raw materials here.

Interviewee 1: I believe there are several aspects here. One being before the product is installed and is located in the value chain. Here there are possibilities of tracing and reuse of the information through the value chain. The other aspect is after the product is installed. For example, today we are marking the pipes of Statens Vegvesen so that they are visible. This is done by adding color to the mixture, making them unique. Other customers has required similar features. However, this may be a bit bothersome. Using signals or mixed-reality to separate the different pipes in the ditch. Then you have information like producer of the pipes, the alloy, raw material, and batch. If you further add sensors it gets interesting. using it for monitoring of leaks or volume control of sand collecting basins. At the same time, you have the issue of products being dug 6 meter down. But I definitely believe there are customer values here, in which are yet to be realized.

Interviewee 2: A possible scenario here would be that the one with all this information available is a major shareholder of the whole value chain, acting as a service provider.

Interviewee 1: An example here is Telenor and Tesla. All Tesla cars are installed with a Telenor sim-card. Telenor asked Tesla how satisfied they were with the signal coverage. Tesla then told Telenor that they had full overview of the coverage of Telenor as they have cars running all over Norway. Suddenly Tesla had this information in which Telenor did not have, illustrating the value of data.

Interviewee 1: The same can be seen in a sewage system. Information on flow and leaks, and control of water distribution. With RFID information (or similar), this control and monitoring could be done in real-time.

Interviewee 2: Tracking leaks would also be possible, in the way that pressure inside the pipe and differences can be used.

Interviewer: Does all products in the two-stage storage connected to a particular customer order?
Interviewee 2: No, not everything. All semi finished good are not connected to customer orders.

Interviewer: So, everything is connected to a specific product, but not necessarily to a specific customer order?
Interviewee 2: Yes. Approximately 340 articles are meant to be delivered the next day. We operate with ABCG classification of products, where G are customer specific products.

Interviewer: Is the current system, M3, able to be integrated with a RFID system?
Interviewee 2: I am not sure, but that is irrelevant as we are in the process of changing system to SAP.

End of interview

Interview 2

Interviewer: Sondre Sivesind Melbye
Interviewee: Purchaser Interview Setting: Interview was conducted during a company visit at Pipelife Surnadal Thursday 3rd of May.

Start of interview:

Interviewer: Hi, can you explain how your process are in relation to the crafting department?
Interviewee: It is based on the planning toll in M3 and the planned production orders. Based on the structure in M3 it triggers orders on articles and intermediary products. I am then responsible for a set of articles, and when it arises a need for any of these articles, it end up at me. Then, there are some things that need to be kept in mind, such

as minimum and maximum amount on storage of a certain product, average usage etc.

When the need ends up at me, I need to place orders on the items. I try to use the same suppliers as long as it is feasible. This for reducing transport costs and CO2 emissions. The order is then sent and I receive an conformation in which I upload to M3. For example, if the lead time shows three weeks and it is due in two, I need to inform about about that to the responsible customer. This require good and precise communication. We try to keep as little as possible on storage, but it is based on the size on the batches. Then it is paying attention and following up the order, for example if there are differences in planned order delivery date and actual order delivery date. Others are responsible for order reception. Here the likelihood for error is high.

Interviewer: There I am thinking that a RFID solution would also be something that affect and benefit not only Pipelife, but also suppliers and customers. In that knowing whether the package is packed, shipped or similar. For example in quality assurance of the package and early discovery of errors in which can be time and cost consuming.
Interviewee: A different challenge is that we struggle on keeping accurate records of certain products. Sometimes due to the product structure. We need to physically check the inventory balance, sometimes for double checking, but mainly as a quality assurance that we have sufficient of certain products.

Interviewer: So that is only on a few certain products?
Interviewee: Yes. I would suggest on around 50 different units.

Interviewer: That is intermediary goods, only for the crafting department?
Interviewee: Yes, intermediary goods, but not only for CD. For CD i believe it is about 10-15 articles.

Interviewee: A different challenge is that during inspection, I may observe an empty inventory and assume that max inventory have to be purchased. Later I may discover that one of the pallets were in the CD and being used, and then put back maybe close to full. At the same time, it may look like we have full inventory, when the actually are only half full. Then we might have less inventory than expected after inspection. Sometimes it is impossible to look into the pallet, for example if the pallet is placed on the top shelf. This is something I hope a RFID solution would contribute to solving.

Interviewer: For the production workers, it is most convenient to bring the whole pallet? Could using a trolley of something be a possibility?
Interviewee: Using a trolley would not happen. Bringing the whole pallet is the way it should be done to save time etc. But an RFID solution may help in location the pallets.

Interviewer: All these products are in fairly large quantum and stored on pallets? Resulting in a not too large amount of pallets?
Interviewee: Not necessarily large quantum, but on pallets, yes. Approximately 3-10 pallets per article. We are currently working with Eye-Watch, a company doing sensors, on having a sensor system monitoring these pallets.

Interviewer: With this solution, would you know whether the pallet is within the factory?
Interviewee: No, we would not know.

Interviewee: We are going to try this system on a couple of pallets/articles. We are also working on a button-system where the operator push a button when there are need for purchasing more items.

Interviewer: This would then include human error as a large source of risk, since the button-system would be very human dependent.
Interviewee: Absolutely. But that might be a quick fix.

Interviewer: How much would real-time data simplify your work?
Interviewee: It would be of much help. In relation to strategic purchasing, where you look at trends etc. could be affected. Maybe even being able to buy larger quantities at fewer times to save costs, and reduce carbon emissions and footprint.

Interviewer: That manual control/inspection was done once or twice a week?

Interviewer: Yes, one ore two times a week. But during busy times maybe even once every two weeks.

Interviewer: How much time do you spend on such a route?

Interviewee: In the beginning it took longer, but now about 45 minutes. During this route I also have dialogues with operators and getting information on items with a high expected short-term need. However, this process are dependent on me. If I'm absent, a different person would spend more time.

Interviewer: That's the end of my questions. Thank you.

End of interview